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ECONOMICS OF RURAL PUBLIC TRANSPORTATION PROGRAMS

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Rural transit systems cannot be expected to be self-supporting. Revenue rarely comes close to the 7 cents/mile (4.4 cents/km) that is typical of the costs of the system. Costs are high because low population density and the great number of destinations in most rural areas cause high per-passenger cost for driver salaries and management. Ridership on subsidized systems that have been set up under the Office of Economic Opportunity and similar auspices tends to be a small fraction of the general population and even the disadvantaged population. Competition from automobile alternatives (car pooling and ride sharing) diminishes the effective demand for transit solutions. Getting programmatic consensus on destinations is difficult because of conflicting alternatives; therefore, ridership is low. A subsidy large enough to provide minimum service levels to all the disadvantaged in a region is beyond what appears to be the fiscal capacity of local governments in rural areas. Few of the original Office of Economic Opportunity experiments have been picked up for sustained local funding. In light of these findings, restricting new expenditures of money for rural transportation demonstration programs to low-cost innovations such as (a) systematized car pooling, (b) transportation vouchers for specific target populations, or (c) consolidating social-service transportation and service delivery programs may be useful.

•THIS paper draws data from reports of rural transportation demonstration programs and from the general literature on rural transportation to answer questions on the costs and economic benefits to be expected from rural transportation demonstration programs. The paper reviews 5 major issues.

1. Can rural transit systems be designed to increase the mobility of residents and still generate sufficient revenues to be self-supporting?
2. If systems cannot be self-supporting, how much and what kind of long-range subsidy will be necessary?
3. Should rural transportation systems be designed as public transit, that is, for everyone, or should they be pointed at specific target populations of the transportation disadvantaged such as the elderly, the physically handicapped, or the carless?
4. How much ridership can be expected in rural transportation demonstration programs that use vehicles and drivers in conventional or demand-responsive programs?
5. What should the emphasis of rural transportation system development be? Should it be developing new transit systems, giving lower fares for existing systems, stimulating ride sharing, or delivering services to the homes of the immobile?

These questions are important because Congress and several state governments will allocate money for demonstration projects in rural areas during 1974. For example, under section 147 of the Federal-Aid Highway Act of 1973, $30 million was authorized for eligible demonstration projects for items such as purchase of passenger equipment and system development; $9.6 million will be spent in 1975. Each of these projects must ultimately be evaluated for its ability to provide economically viable service to remote areas. To the extent that the projects fail to be self-sustaining, the taxpayers must rank transportation aid high enough on their list of priorities to maintain the experiments, or the expenditure will set up only temporarily useful systems.

REVIEW OF LITERATURE ON RURAL TRANSPORTATION PROGRAMS

The literature on rural transportation can be classified into 3 categories. The first category, prevalent in the early seventies, offered general recommendations for alleviating problems of immobility. This advice on the need for improved mobility among the transportation disadvantaged offers little analysis of the costs to be expected in providing new services or of the economic benefits that would occur. The studies did, however, provide important insight into the plight of Americans who did not exhibit the usual patterns of mobility. For example, Dickey (4) wrote:

> Only fifty percent of poor households in rural areas are likely to own a car. As a result they will make only 15 percent of the trips an average American makes. Many of the aged will have to leave their homes and be placed in institutions. Handicapped and elderly people may not be able to receive adequate medical attention.

The second category was the local feasibility study, which often was triggered by the possibility that Office of Economic Opportunity (OEO) funding could initiate a transportation program on a local, experimental basis (5, 6, 7). These feasibility studies customarily identified target populations of persons within the area and specified a transportation facility to augment sparse or nonexistent public transit in the region. These studies typically did not deal with where money would come from for a long-term, self-sustaining program. They concentrated on unsubstantiated estimates of the latent demand prevalent in the area and on showing the failure of private enterprise to respond to those demands.

The third category is the follow-up evaluation of completed experiments. These studies are more likely to explore questions of economic costs and benefits, which Burkhardt (8) does in his study of an OEO-sponsored transit program in Raleigh County, West Virginia. However, the reports on individual projects do not assess the overall question of the economic viability of such programs, for each necessarily deals with the unique features of topology and system design of the single experiment. Some general questions about the economics of rural transportation programs need to be asked. To answer the questions posed at the start of the paper, the data on ridership patterns, latent demand, costs, and economic consequences of new transportation programs in rural areas must be reviewed.

RIDERSHIP

Ridership in public transit programs offering daily service is very low. It is the exceptional program that draws more than a tiny fraction of the rural population into daily ridership. Data given in Table 1 indicate that, in many of the experimental programs, only a small fraction of the potential ridership actually make it a practice to ride buses, minivans, or other systems set up under government auspices. Yet we are constantly reminded in the advisory literature that the transportation disadvantaged in the rural areas account for up to 50 percent of the rural population in areas where the programs were set up. (It should be noted that these data refer only to transportation systems operating on a daily basis for the general public. Special-clientele systems will be discussed later.)

In the feasibility studies, ridership often has been anticipated to amount to several hundred percent more than that which actually materializes when the program runs its course. Why is this so? Faulty designs for tapping latent demand may be the problem. One approach is to use census data to establish the trips per person per day prevalent in an area and then to see how far the rural region in question falls short of the national average. This approach to latent demand assumes a homogeneity in trip-generating characteristics of differing populations that does not appear to be able to be reconciled with the facts. For example, the national average of trips per person per month is 67.25 according to Burkhardt (8), but, in rural areas of North Carolina, only 10.1 trips/person are made. If the deficiency were on the supply side, provision of subsidized transit service would increase trip making by several hundred percent. Yet experiments in certain rural North Carolina counties show that the institution of a new bus route may promote new riding patterns in only 1 or 2 percent of the population.

Another inappropriate measure of latent demand is that which results from population surveys in which the question, Would you use new bus service if it were set up? is asked. Most respondents readily assert that they would use new bus service, but in actual practice, the carless worker often prefers to ride in a car pool rather than wait for a bus. One may speculate that the bus trips, which wend their way over thinly settled territory, must delay early-boarding passengers by frequent stops to pick up enough patrons to justify a trip.

Many of the reports evaluating specific transportation projects camouflaged the low level of ridership by various devices including

1. Reporting "peak-load" data,
2. Tallying trips over an entire month or year to report numbers of passengers in the thousands, and
3. Neglecting to compare actual ridership with local area population.

Ridership in some cases is impressive, but these experiments reflect accidents of topography for system design not usually found in the average rural transportation site. For example, Burkhardt (8) found that, at the end of the project, 5 buses were in use in Raleigh County that were operating at more than 110 percent capacity. The long, narrow valley of the regular bus routes facilitated high ridership rates.

Apologists for rural transit programs may say that these figures are not any worse than for transit ridership in urban areas and thus do not reduce the justification of new experiments of a similar nature. However, because the costs of these rural programs are very high on a per-person basis, these statistics on ridership raise serious questions about the economic advisability of such programs. But, fortunately, some substantial social benefits go along with high costs in specialized transportation programs such as those that set up special routes to medical facilities.

COSTS OF SYSTEMS

Costs vary tremendously depending on the type of program initiated. A U.S. Department of Transportation (DOT) report (9) estimated that the cost per vehicle mile varies from 33 cents to 60 cents (20.6 and 37.5 cents/vehicle km) for systems with professional drivers providing full-time transit service. Chen (10) found costs from 37 cents to 92 cents/vehicle mile (23.1 and 57.5 cents/vehicle km). Let us examine the sources of variation.

1. Salaries usually make up the major part of a transportation dollar in systems in which drivers are employed full time. For example, the data given in Table 2 (13, p. 22) indicate how costs are divided. Salaries generally use 60 percent of the program budgets for which there are data. If the drivers can be hired at minimum wages (an impossibility in many unionized areas) or if they can be hired to work only on a part-time, peak-load basis, costs can be cut considerably. In a number of rural systems, drivers make a run only once or twice a day on their own trips. Thus costs are cut considerably below comparable figures for urban areas.

2. Administrative overhead also varies considerably from project to project. Particularly in OEO-sponsored projects, generous allowances for managerial overhead usually were figured into the budgets early. Greater fiscal stringency later in the projects appears to be accompanied often by reduction in management overhead. A project may start with a full-time manager plus an assistant. Later only a part-time manager is used. Further research should examine whether a project could have been initiated and sustained with the lower level cost.

Table 1. Selected characteristics of rural transit programs with daily service and general clientele.

System Name	Population of Counties Served	Estimated Monthly Ridership	Number of Vehicles	Passengers/ Weekday Vehicle	Daily Ridership/ Population
Southeast Arkansas CAA, Warren, Ark.	92,000,000	600	25	1.1	0.00001
Mid-Delta Community Service Transportation, Helena, Ark.	6,300,000	600	5	5.5	0.0009
Northeast Kentucky Area Development Council, Olive Hill, Ky. (service soon to be reduced to 4 counties)	94,000,000	350	13	1.2	0.00001
Rural Community Bus Lines, Annapolis, Md.	291,300,000	1,400	3	21.2	0.00007
Nash-Edgecombe Economic Development, Inc., Rocky Mount, N.C.	195,000,000	3,000	3	45.5	0.0002
Project STRIDE, Warren, Pa. (no longer operating)	89,700,000	4,050	12	15.3	0.0002
Venango Action Corp. Rural Outreach, Franklin, Pa.	62,300,000	2,000	3	30.3	0.0005
Cooperative Transportation, Kingsport, Tenn.	243,000,000	3,000	6	22.7	0.00009
Tri-Parish Progress Transportation System, Crowley, La.	175,544,000	1,000	5	9.1	0.00005
Raleigh County Community Action Bus System, Raleigh County, W. Va.	70,000,000	3,600	6	27.2	0.0004

Table 2. Average annual cost data per vehicle from 12 rural transit systems for 1973.

Item	Cost of System With Seat Capacity Under 100		Average Cost of All Systems	
	Dollars	Percent	Dollars	Percent
Salaries				
Administrative and other	5,799	44	3,578	30
Drivers	2,390	18	3,370	29
Total	8,189	62	6,948	59
Other costs	4,950	38	4,873	41
Total costs	13,139	100	11,821	100

Table 3. Average annual operating costs per vehicle mile (kilometer) per trip from 12 rural public transportation systems for 1974.

Item	Seating Capacity of System: Under 100		100 to 200		200 to 300		Over 300		All Systems	
	Cents/ Vehicle Mile	Percent	Cents/ Vehicle Mile	Percent	Cents/ Vehicle Mile	Percent	Cents/ Vehicle Mile	Percent	Cents/ Vehicle Mile	Percent
Total fixed cost	40	70	19	31	23	34	47	51	34	46
Total variable cost	18	30	43	69	41	66	45	49	39	54
Total cost	58	100	62	100	64	100	92	100	73	100

Note: 1 cent/vehicle mile = 0.625 cent/vehicle km.

3. Equipment and maintenance costs are significant and sometimes substitutable. Economies in capital acquisition (buying old vehicles) result in higher repair costs. Depreciation of new equipment tends to run at a rate of 10 percent/year. Equipment size should be minimized and equipment should be bought new.

Interestingly, there are no scale economies or diseconomies immediately apparent in these systems because vehicle size and numbers of vehicles in the systems can be adjusted to fit the demand patterns of varying localities with no major cost effects on vehicle-mile (vehicle-kilometer) costs. From the data given in Table 3 (13, p. 22), one notes that the costs run around 60 cents/vehicle mile (37.5 cents/vehicle km). The only exception is the system with seating capacity over 300; for this system, there is only 1 observation. Potentially high-scale diseconomies do not show up in the data because past costly systems no longer exist.

In light of low ridership and high vehicle-mile (vehicle-kilometer) costs, average trip costs per passenger-mile (passenger-kilometer) are about 7 cents (4.4 cents/passenger-km) and, because rural trips can average 100 miles (160 km) round trip, average trip costs can range anywhere from $3.86 to $10.51/passenger. To date, no transit program in rural areas has come close to bringing in the passenger fares needed to cover these costs. DOT has noted that the psychological limit on pricing is 2 to 5 cents/passenger-mile (1.2 to 3.1 cents/passenger-km). Although some round-trip fares run as high as $4.50, they generally are set around $0.50 to $1.00, which covers less than half the costs of operation (9). Special charters and school bus programs appear to cover costs and bring in revenues based on bunched destinations and origins (simulating urban densities) or on implicit subsidy through school budget processes (9). Thus one may conclude that, if costs run to 7 cents/passenger-mile (4.4 cents/passenger-km) and revenues run to no more than 5 cents/passenger-mile (3.1 cents/passenger-km), then a substantial deficit will occur (5). The Comsis report (5) stated:

> It appears that the private transit operator in the State of Minnesota has been put in the position of subsidizing regular route service using profits from charter, special, school bus and other operations. In 1971, the average cost of providing one bus-mile of transit service was 57 cents. The associated revenue derived from one bus-mile of transit service varies by type of service—69 cents for charter and special service, 61 cents for school bus service, and 34 cents for regular route service. On the average, costs exceeded revenue by 23 cents per bus-mile of regular route service provided in 1971.... During the period 1967-71, the industry reduced regular route service, measured in terms of bus-miles, by 27 percent.

It should be noted that these figures apply only to paid driver systems.

SUBSIDIES

One may conclude that rural transportation systems involving drivers picking up passengers cannot usually be expected to be self-supporting systems. Furthermore, the amount of subsidy that will be necessary is considerable; it typically is 30 to 60 percent of total costs. One may further question the validity of subsidy programs because the beneficiaries, as has been shown, are a small minority of the transportation disadvantaged. For example, to double the mobility of the transportation disadvantaged in North Carolina, one would have to spend $495,000/month based on a rate of 10.1 trips/month for an average trip of 50 miles (80 km) at 7 cents/passenger-mile (4.4 cents/passenger-km) for 14,000 persons. However, the benefits of many of these systems come from their serving persons who have been isolated from activity solely because they do not have access to private transportation. In a survey of the carless population in the rural areas surrounding Greensboro, North Carolina, 63 percent who shopped traveled by car pooling or ride sharing. Another 22 percent walked. Only 3 percent traveled by bus. It is doubtful that routes could be set up to attract much more than 5 to 10 percent of the population to new bus service. Yet this 5 to 10 percent may find new life-styles and great enjoyment of their increased mobility.

Economists are inclined to discourage the use of subsidies to particular economic producers because the money flow prevents the weeding out of inefficient producers. An opposing view is that transportation should be viewed as a public utility, subsidized for the external economies it brings as measured by economic development, freedom to the individual, or some other nonmonetary advantage (11). Further research will have to demonstrate whether providing transportation programs in rural areas will stop people from moving away by connecting people with jobs.

Data from a study of carless residents in the Greensboro, North Carolina, hinterland suggest that the carless residents of an area typically suffer higher unemployment or experience lower wage rates by 62 cents/hour. [This figure comes from a survey of 387 residents of rural areas within a 50-mile (80-km) radius of a major employment center, Greensboro, in the industrialized Piedmont crescent area of western North Carolina.] If mobility brings in economic returns, then riders may be asked to pay for the cost of the system. Subsidies, however, may be justified as a useful social investment that permits the increased mobility of the transportation disadvantaged to needed social services, medical care, and community contacts. Again the question must be asked: Realistically, how many of the transportation disadvantaged will use the service for these purposes? As noted, data on ridership show that selected programs (Headstart and medical delivery) have had high ridership in North Carolina, but such programs must be carefully designed and funded. Unfortunately, the spirit of generosity that could sustain subsidies for social investment of this nature appears to dim as county commissioners and other local officials contemplate budget tightening. Few of the OEO demonstration programs were picked up by local government. However, some states, such as Missouri and Pennsylvania, have invested heavily in rural public transit programs.

INNOVATIONS IN SERVICE DELIVERY

For the reasons that have been cited, transportation planners have been giving increased attention to innovations that are lower cost solutions. One experiment of great interest is that conducted in Warren County, Pennsylvania, where promotion of ride sharing obviated the need for paid drivers. This program again served only a small fraction of the target population, but it can serve as a useful prototype of a limited system. Another approach favors the direct subsidy of passengers rather than transit systems. In Raleigh County, West Virginia, a transportation-reimbursement incentive program will attempt to improve the mobility of the disadvantaged. However, vouchers for transportation are equivalent to a selective fare reduction, and some experts suspect that availability of service is more important than low fares are in attracting ridership. Kraft and Domencich (12, p. 4) state that

> . . . while free transit does, in general, contribute to the goals that its supporters seek to achieve, improved transit service is generally a more efficient means of promoting these objectives. The evidence indicates that transit ridership is more responsive to improvements in service than to reductions in fares; and reductions in access times to and from the transit station, as well as transfer and waiting times are likely to be particularly important in this regard. The available evidence suggests, however, that even substantial improvements in transit services are not likely to reduce greatly the demand for automobile travel.

The voucher system does have the merit of encouraging use of various modes including car pooling, and, because carless individuals are still very car-oriented, the program may fit current travel modes well.

Another approach that should be given consideration is that of redefining the rural transit system from a people mover to a goods-and-services mover. Could rural transportation be looked at not only from the point of view of bringing the population to nontransit services but also from the point of view of bringing nontransit services to the population? Examples that come to mind are the meals-on-wheels programs that deliver food to shut-ins or the emergency squads that fly into remote areas to assist in health-delivery programs. Because many of the so-called transportation disadvantaged are elderly or physically incapacitated, they may not be able to respond to new transportation programs set up in the neighborhood. Indeed, this may be one reason for low ridership. Rural demonstration program money could consider designing mobile vans (similar to bookmobiles) to get welfare checks and food stamps to low-income families and provide visiting nurse programs. These programs appear to bring greater coverage to the target populations, yet they experience transportation difficulties and high costs resulting from disparate programs. Consolidation of social-service delivery could be an important element in rural transportation demonstration programs.

SUMMARY AND CONCLUSIONS

In general, rural transit systems cannot be expected to be self-supporting. Revenue rarely comes close to the 7 cents/passenger-mile (4.4 cents/passenger-km) that is typical of the costs of the system. Costs are high because low population density and a great number of destinations in most rural areas cause high per-passenger cost for driver salaries and management. Ridership on subsidized systems that have been set up under OEO and similar auspices tends to be a small fraction of the general population and even the disadvantaged population. Competition from car alternatives (car pooling and ride sharing) diminishes the effective demand for transit solutions. Getting programmatic consensus on destinations is difficult because of conflicting alternatives; therefore ridership is low. A subsidy large enough to provide minimum service levels to all the disadvantaged in a region is beyond what appears to be the fiscal capacity of local governments in rural areas. Few of the original OEO experiments have been picked up for sustained local funding. In light of these findings, restricting new expenditures of rural demonstration money to low-cost innovations such as (a) systematized car pooling, (b) transportation vouchers for specific target populations, or (c) consolidating social-service transportation and service delivery programs may be useful.

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ESTIMATING COST OF PROVIDING RURAL TRANSPORTATION SERVICE

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The issue of rural transportation has attracted the attention of public policymakers. Now that the general need has been recognized, decision makers want to move to the important questions of demand and cost. Despite the existence of hundreds of small-scale transportation systems, many of which are rural, very little research on demand is available to guide the would-be designer of a rural transportation system. This paper reports work done by the Governor's Rural Transportation Task Force in Pennsylvania. Among the task force objectives was estimating demand for and cost of transportation in all rural areas of Pennsylvania. Based on what little documentation of demand for public transportation systems in rural areas is available, a range of demand estimates is produced. Alternative service options are introduced to show their influence on final costs. These 2 factors—level of demand and level of service—appear to be the most significant determinants of the cost of rural transportation systems.

•THE 1960s was a time of awakening of America to the plight of cities and residents of cities. Major federal projects were undertaken to meet a host of problems in fields ranging from housing to health care, from education to urban renewal, and from poverty to transportation. The thrust of these activities was directed at making the cities somehow "better." The field of transportation was no exception.

Decisions made in the 1950s regarding major highways in the cities were implemented in the 1960s. With this implementation came concern that a multimodal answer was necessary if the cities' transportation systems were to be better. The Housing Act of 1961 contained the first important federal commitment to the improvement of urban mass transportation. It was followed by the Urban Mass Transportation Act of 1964, which greatly broadened and strengthened the federal role and institutionalized the principles that guided federal public transportation policy until the Federal-Aid Highway Act of 1973. These principles included limiting aid to transportation systems in urban areas. Rural areas were excluded from principal federal transportation assistance efforts. Only in social welfare programs established as part of the War on Poverty and the Great Society were federal dollars for transportation services in rural areas made available. Not until the passage of the Federal-Aid Highway Act of 1973 with section 147, which authorized the Rural Highway Public Transportation Demonstration Program, were the public transportation needs of rural America officially recognized as being a legitimate concern of the nation's emerging transportation policy.

The 1970s has brought a renewed interest in rural America and the problems faced by its inhabitants. As has been outlined, the federal approach to solving transportation problems finally has been broadened to include rural areas. If the seeds for solving urban mass transportation problems were sown in the 1960s, then the same is true for rural public transportation problems in the 1970s.

With the demise of the great interurban networks and the shrinkage in recent years of bus and taxi service in rural areas, large portions of rural America have become increasingly dependent on a single mode of local and intercity passenger travel—the

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automobile. If all persons living in rural areas had access to automobiles whenever they wished to travel, this dependence might not cause problems. In fact, the comparatively low density that characterizes rural areas makes them ideally suited for the automobile. However, the reality is that automobile availability is not universal in rural areas. Thus, as in urban areas, a portion of the rural population is transit dependent.

As public attention turns toward the transportation problems of rural residents, analytical skills and techniques must be developed that can be used to determine the magnitude of the problems and can readily portray possible solutions in economic terms that can be easily understood by policymakers. The purpose of this paper is to outline one such approach to estimating the cost of providing rural transportation services. The method outlined was developed during the course of an inquiry into the rural transportation problems of Pennsylvanians by the Governor's Rural Transportation Task Force during the spring of 1974.

DEMAND ANALYSIS BASED ON EXISTING RURAL TRANSPORTATION SYSTEMS

If one were willing to pay any price for goods or services to fulfill a need, no investigation into the cost of the goods or services would be warranted. However, in developing public policy and programs, this luxurious approach cannot be tolerated. A need must be identified, quantified, and evaluated before appropriate steps can be efficiently taken to meet the need. Public transportation in rural areas is one need that has not received general consideration. Yet demands for better rural public transportation are increasing. As social service centers and programs become more widespread, the recognition has grown that they can usually benefit their intended clients only if the clients can travel to places where the services are offered.

In the past 10 years, there have been numerous organized small-scale efforts to meet variously perceived transportation needs. The typical effort has been to implement small demonstration projects with a few vehicles operating in a relatively small territory, serving an often ill-defined clientele, and using seed money from a social service program. Usually, little analytical work preceded the project implementation. Most often, any analytic work was directed at identifying funding sources. Quantifying the need for the service usually was not done. A general description of the potential clientele with information such as the number or percentage of elderly, below-poverty households and the like was all that was included. When sufficient funds were ensured to put vehicles on the road, the project went into operation. When the funds expired the project ended.

Before serious, long-term, large-scale efforts are undertaken, careful analysis of the need or demand for rural public transportation service and the cost of providing service to meet the identified demand must be made. When this is complete, the financial feasibility of the proposed undertaking can be evaluated. The work of the task force was the first attempt to do this for Pennsylvania as a whole.

BASIC DEMAND ASSUMPTIONS FOR PENNSYLVANIA

The demand identified for rural public transportation service and, especially, the cost of meeting the identified demand are sensitive to a number of issues. Each must be defined before an analysis can proceed. Rural areas include all areas outside the urbanized areas identified for the most recent U.S. census (except small urban areas). Small urban areas include all cities and boroughs located outside urbanized areas. Rural public transportation includes public transportation wholly within rural areas or small urban areas or between rural areas or small urban areas and the boundary of urbanized areas. Demand for rural public transportation is the number and length of trips that would be taken on public transportation by residents of rural and small urban areas at a given level of fare and level of service. Demand can be expressed in passenger-miles (passenger-kilometers).

When demand for rural public transportation in Pennsylvania was calculated, any rural public transportation system was assumed to operate at no fare for persons 65 years old or older (in accordance with existing state programs), at reduced or no fare for low-income nonelderly citizens, and at 25 cents or 5 cents/passenger-mile (15.6 or 3.1 cents/passenger-km), whichever is greater, for everyone else. The free senior citizen rides would be funded, as in urban areas, from the state lottery; the reduced fares or free rides for low-income persons would be paid for through modification of existing or proposed social welfare programs. Any general subsidy required to keep the overall fare structure at the level just discussed would come from unspecified state revenues.

Because the justification for a government-supported rural public transportation service rises primarily from the unmet transportation demand of transit-dependent persons (captive riders), it was assumed that the level of service offered would have only a marginal influence on the demand for the service. Level of service, however, has a great effect on the cost of providing the service. Because of the relative inelasticity of demand, certain assumptions regarding the characteristics of the service to be offered were made in order to calculate the total number of passenger-miles (passenger-kilometers) of demand. These assumptions were based on observed facts and included 4 points.

1. The most likely trip purposes to be served by a rural public transportation service are shopping, medical, personal business, and social-recreational trips; work trips are of only minor importance.
2. Most of the trip purposes can be satisfied by destinations in county seats or cities and boroughs of at least 5,000 in population. These municipalities are designated service centers, and a policy decision was made that patrons would be carried to the nearest point at which the trip purpose could be fulfilled.
3. Each center is the focal point or centroid for the development of a theoretical natural transportation service shed. Each shed is initially defined by bisecting the distance between each service center and every adjacent service center. The boundaries can then be adjusted to compensate for physical features such as mountains, rivers, and the highway network. Performing this exercise for Pennsylvania produced service shed boundaries that closely approximated existing county boundaries in most cases.
4. Average person-trip lengths could then be estimated by calculating the average airline distance between a centroid and its service shed boundaries. The average airline distance was multiplied by an adjustment factor of 1.5 to account for the difference between highway distance and airline distance, and then this product was multiplied by 0.5 if the population density was reasonably similar throughout the service shed. The resulting value is the estimated average 1-way person-trip length for potential patrons of a rural public transportation system within a given service shed if no unusual population settlement patterns in the service shed are assumed.

When this method was applied to Pennsylvania, it produced average person-trip length estimates in a range of 9 to 15 miles (14.4 to 24 km) for most of the state depending on the settlement pattern. This was consistent with the average person-trip length of 11 to 12 miles (17.6 to 19.2 km) experienced in a rural transportation demonstration program operated by the Pennsylvania Department of Agriculture. When a value for the average person-trip length is computed and the number of person trips is estimated, then the number of passenger-miles (passenger-kilometers) of demand can be calculated

ESTIMATING DEMAND

Although there is a large body of literature and experience for urban public transportation demand, there are few data and little experience available to estimate the precise level of public transportation demand. Most planning documents reviewed that were developed to lay the groundwork for the implementation of rural transportation services sidestep the question of demand. Frequently, such reports statistically describe the population groups living in the service area and nothing more. Occasionally a report will set goals for the number of persons that hopefully will use the proposed service when it is implemented.

Low Estimate

One way to estimate rural public transportation demand is by using ridership experience data developed for existing rural transportation services and applying the measures developed to rural Pennsylvania. A useful value to use in estimating potential system usage is annual ridership per person.

A recent report prepared for the Urban Mass Transportation Administration contained statistics that indicated that the annual transit ridership in rural areas of the United States in 1960 was 3.5 revenue transit rides/person (1). By 1970, this rate had fallen to 2.8 annual revenue transit rides/person. If this downward trend continued, it is likely that the 1974 rate is about 2.4 annual revenue transit rides/person. The same report showed annual per-person revenue ridership figures in small urban areas of 10.0 in 1960 and 5.0 in 1970. If this trend continued, the likely value for 1973 is 4.0 annual revenue transit trips/person.

Another estimate of rural public transportation per-person ridership can be derived from data presented on 2 systems operating in Florida. The CATS service operating in Brevard County has a ridership of 0.8 trips/person/year (2). The Suwannee Valley Transit System, which serves a 4-county rural area in northern Florida, was experiencing a rate of 0.6 trips/person in the rural portion of the counties and 1.9 trips/person in the 2 major urban communities (Lake City and Live Oak) that it serves. Comparable figures for Pennsylvania are difficult to establish. However, a review of data collected from transit companies participating in the free transit program for senior citizens indicates that ridership in small urban areas ranges from 0.6 to 4 transit trips/person/year, and 0.5 to 3 transit trips/person/year for companies whose service areas are strictly rural. An attempt was made to establish similar measures for non-common-carrier transportation operations such as those operated by community action agencies or other social service organizations. Unfortunately, most of these operators keep no record of the number of persons carried. An exception is the Venango County, Pennsylvania, system, which reported approximately 20,000 person trips in a 1-year period. This would represent about 0.3 rides/person/year based on a county population of 62,000.

With these factors, ranges of estimated potential patronage can be developed for rural public transportation services. The 1970 U.S. census reported Pennsylvania's total population as 11,793,909 with 6,921,679 persons living within the state's 13 major urban areas. An additional 1,508,431 persons lived in other urban areas with populations of at least 2,500. The remaining 3,363,499 persons live in rural areas. Table 1 gives estimates of the potential number of annual transit trips that could be expected to be made if service were available to rural residents. Averaging the figures derived in Table 1 would yield an annual estimate of 3.5 million rural transit trips and 3.3 million small urban trips. Of course, these estimates assume that transit trips would continue to be made at rates consistent with current experience. Obviously, many factors, including type, cost, frequency, and quality of service provided, could affect this greatly.

High Estimate

Although the previous estimates are for the population at large, persons with certain characteristics may use a public transportation service much more than the norm. A study of the transit habits of poverty households in rural West Virginia revealed a transit-riding propensity of 19 rides/person/year (3, 4). Pennsylvania's experience with the free transit program for senior citizens has shown that, in many urban areas, ridership among senior citizens has ranged between 24 and 36 annual transit trips/senior citizen. Comparable values in rural areas are on the order of 10 to 15 annual transit rides/senior citizen. Obviously, if an area has an exceptionally large proportion of elderly or low-income persons or both in its population, then the potential demand for public transportation services is likely to be higher than average.

By using these ridership factors, one can develop another estimate of rural transportation demand based on a high degree of system usage by elderly and low-income persons and the assumption (based on prior experience) that these persons represent approximately 80 percent of total system ridership. Thus the estimated total ridership will equal the estimated senior citizen ridership plus the estimated low-income ridership divided by 0.8.

System Implications of Demand Levels

Demand such as that mentioned could be handled in a number of different ways in various areas of the state, depending on the density of demand. There are approximately 40,200 miles^2 (104 520 km^2) in rural Pennsylvania excluding urban areas, federal lands, and water surface. Thus the average rural transportation demand density (assuming that the low estimate of demand is accurate) would be approximately 87 annual demands/mile^2 (33 annual demands/km^2) or 7.3 monthly demands/mile^2 (2.8 monthly demands/km^2) or 0.24 daily demands/mile^2 (0.09 daily demands/km^2). The average rural county contains nearly 620 miles^2 (1612 km^2) and thus could expect approximately 149 demands for service daily, which is a low level of demand that can be served only at high cost. The cost of serving these demands most likely can be reduced if the demands for service can be structured in terms of both time and geographic location. The 149 daily demands for service was calculated by assuming that service would be offered every day in the county. If the service were offered only 6 days/week, then the average daily demand for service would be 170 daily demands, which is still a low level of demand. Also the service to meet the demand need not be offered 24 hours/day, but rather during specified time periods during the day.

If we assume that the high estimate of demand is accurate, then the density of demand would be 269 annual demands/mile^2 (102.2 annual demands/km^2) or 0.73 daily demands/mile^2 (0.28 daily demands/km^2). For the average county, this translates into 453 daily demands for service. Although this is a more serviceable level of demand than before, the same comments still apply. Given the geographic dispersion, we are still at the high end of the cost scale for service. Structuring the demands geographically and temporally would significantly reduce the cost. Geographically, it is not likely that the demands will be dispersed uniformly across the county. Concentrations will occur in small villages and along the main roads. Thus, differing amounts of service could be offered to meet varying demand patterns. Some areas might require service several times per day; others might require service only once per week.

Passenger-Mile (Passenger-Kilometer) Calculations

By using a statewide average trip length of 12 miles (19.2 km), one can estimate the number of passenger-miles (passenger-kilometers) of service needed in rural areas of the state. As calculated from the data given in Table 1, the annual demand for rural public transportation is 3.5 million person trips. If these trips average 12 miles (19.2 km), service to handle 42 million passenger-miles (67.2 million passenger-km) of demand annually is needed in rural areas. Based on the calculations given in Table 2, the 10.8 million person trips converts to 129.6 million passenger-miles (207.4 million passenger-km). Thus the demand in rural areas alone could range from 42 million to 129.6 million passenger-miles/year (67.2 million to 129.6 million passenger-km/year).

Based on experience found in urban transit operations the average transit trip lengths in small urban areas were calculated to be approximately 1.5 miles (2.4 km). Thus, based on the data given in Tables 1 and 2, the low estimate of annual demand for small urban public transportation would be 5.0 million passenger-miles (8 million passenger-km), and the high estimate would be 10.4 million passenger-miles (16.6 passenger-km). In summary, there is an estimated need for service to accommodate 47 million passenger-miles (75.2 million passenger-km) of demand to handle the low estimate of demand and 140.0 million passenger-miles (224 passenger-km) for the high demand estimate.

SYSTEM COSTS

As previously explained, the amount of travel that might be served by a rural transportation system in Pennsylvania was estimated to range from 6.7 to 17.7 million trips/year. Estimates of trip length were made, and the total annual passenger-miles of service required was calculated to be from 45.8 million to 140 million (73.3 to 224 million passenger-km). If an occupancy rate in vehicles of 18 percent is assumed and if the low estimate of the demand is served, then the total annual costs (operating and capital) could range from $3.8 million if large transit vehicles are used to $16.8 million if automobiles (with paid drivers) are used (Table 3). If the high estimate of the demand is served, then the annual operating costs could range from $11.7 million if large transit vehicles are used to $51.3 million if automobiles are used.

If we assume that a 33 percent load factor could be achieved, then the total annual costs (for low demand) would range from $2.08 million if large buses are used to $9.16 million automobiles are used. For the high demand figure, total annual costs would range from $6.36 million to $28.0 million.

Pennsylvania is now spending approximately $3 million/year in state funds to provide transportation services (excluding pupil transportation) in rural areas (5). These funds are being spent in an uncoordinated fashion. Because the $3 million figure approximates the low end of the projected cost of an integrated rural transportation system, current level of state expenditures might cover a significant portion of the costs of such a system, and adding existing federal funds would further increase the available resources.

The extreme points of the cost range for low demand are $0.31 and $2.51/trip. For high demand, they are $0.36 to $2.90/trip. This works out to a range of $0.05 to $0.37/passenger-mile ($0.03 to $0.23/passenger-km). These cost limits are based on the assumption that any of 6 types and sizes of vehicles (car; van; small, medium, or large transit bus; or school bus) could be used. Undoubtedly, a mix of types of vehicle will be used and 3 types (van and small or medium transit bus) will predominate. Cost per trip for these three vehicle types should range from $0.46 to $1.75 for low demand to $0.53 to $2.02 for high demand. Cost range per passenger-mile should be between $0.07 and $0.26 ($0.04 to $0.16/passenger-km). The deviation of these cost ranges (which depends on assumptions about level of demand, utilization, and vehicle type) is given in Table 4.

SUMMARY

One of the important features of this exercise was that it identified crucial points in the analysis where varying assumptions could make crucial differences in costs. The most crucial issue was felt to be the estimation of demand. After that is accomplished, specific service characteristics become crucial. All of the process requires the active participation of policymakers who are sensitive to the trade-offs between increased costs and increased services.

The process identified in this project is shown in Figure 1. The basic policy decisions concerning who is served and why initiate the sequence. Demand estimates, which must be increasingly backed by the actual results of implemented projects, are then made for the population to be served. Alternative strategies for meeting the demands may have significantly different cost implications. In particular, efforts will be necessary to concentrate demand in rural areas so that cost-effective transportation service can be provided. When these costs are known, estimates can be derived of potential revenues

Table 1. Low estimate of potential annual transit trips in rural and small urban areas.

Type of Area	Population (millions)	Annual Trips per Capita	Potential Annual Transit Trips (millions)	Type of Area	Population (millions)	Annual Trips per Capita	Potential Annual Transit Trips (millions)
Rural	3.4	0.3	1.02	Small urban	1.5	0.6	0.90
		0.6	2.04			1.0	1.50
		0.8	2.72			1.9	2.85
		2.4	8.16			3.4	5.10
						4.0	6.00

Table 2. High estimate of potential annual transit trips in rural and small urban areas.

Item	Rural Area	Small Urban Area
Population		
Senior citizens	316,000	190,000
Nonelderly low-income persons	255,000	111,000
Annual trips per individual		
Senior citizens	12	18
Nonelderly low-income persons	19	19
Annual ridership		
Senior citizens	3,792,000[a]	3,420,000[a]
Nonelderly low-income persons	4,845,000[a]	2,109,000[a]
Captive	8,637,000	5,529,000
Annual rides	10,800,000[b]	6,900,000[b]

[a]Derived by multiplying population by annual trips per individual.
[b]Derived by dividing annual captive ridership by a factor of 0.8.

Figure 1. Cost analysis process for rural transportation.

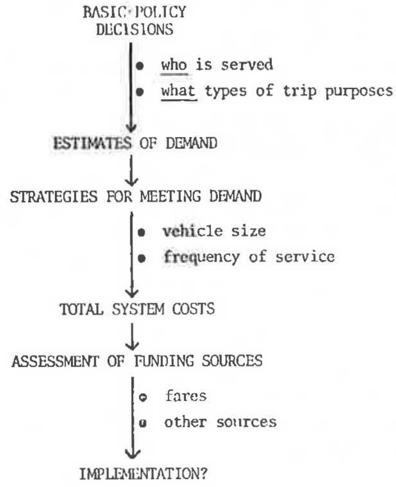

Table 3. Total annualized costs.

Demand	Costs (millions of dollars)					
			Transit Bus			
	Car	Van	Small	Medium	Large	School Bus
Low						
33 percent load factor and 138.8 million seat miles	9.16	6.38	4.72	3.05	2.08	2.22
18 percent load factor and 254.4 million seat miles	16.79	11.7	8.65	5.6	3.82	4.07
High						
33 percent load factor and 424.2 million seat miles	28	19.51	14.42	9.33	6.36	6.79
18 percent load factor and 777.8 million seat miles	51.33	35.78	26.45	17.11	11.67	12.44

Note: 1 seat mile = 1.6 seat km.

Table 4. Typical costs per passenger-mile (passenger-km) and per passenger trip for proposed rural transportation system operations.

Vehicle	Cost per Passenger-Mile (dollars)		Cost per Passenger Trip (dollars)			
			Low Demand[a]		High Demand[b]	
	33 Percent Load Factor	18 Percent Load Factor	33 Percent Load Factor	18 Percent Load Factor	33 Percent Load Factor	18 Percent Load Factor
Car	0.200	0.367	1.367	2.506	1.582	2.900
Van	0.139	0.256	0.952	1.746	1.102	2.021
Transit bus						
Small	0.103	0.189	0.705	1.291	0.814	1.494
Medium	0.067	0.122	0.455	0.836	0.527	0.967
Large	0.045	0.083	0.310	0.570	0.359	0.659
School bus	0.049	0.089	0.331	0.608	0.384	0.703

Note: $1/passenger-mile = $0.625/passenger-km.

[a]6.7 million passengers. [b]17.7 million passengers.

from fares and other funding sources. Only after all these steps have been completed will the policymaker be able to determine the relative worth of the proposed rural transportation effort.

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PROFILE OF A CARLESS POPULATION

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A survey was carried out in which 401 respondents in Buffalo, New York, were queried on car accessibility, activity choice, travel mode choice, and attitude toward travel modes and activities. The purpose of the survey was to examine the differences in travel behavior between those who had access to and use of a car and those who did not. Of the households without cars, only 21 percent never had access to a car. The carless sample showed a profile that was predominately low income, female, elderly, and unemployed. The largest segment of those identified as carless lived in the most densely populated portions of the city. Discriminating among modal-use patterns and activities of the various respondent groups was possible. The carless shopped for groceries more often (by walking) and participated in other neighborhood-centered activities more often than did those with cars. Paid social activities were engaged in much less frequently by the carless group. Walking was an important mode for the carless, but the bus was used by most of them, at least occasionally, for all but grocery trips.

•AN IMPLICIT belief among planners is that those without cars belong to a larger group referred to as the transportation disadvantaged (1, 2, 3). To gain some measure of the degree of disadvantage of this group, we have made a study of the travel habits and needs of those without cars.

The carless are not a homogeneous group. In a previous paper (4), various subgroups of this population have been identified, and their general locations within a large metropolitan area have been established. The field location of members of these groups is not as simple a task as may be assumed from a study of the literature cited (1, 2, 3, 4). One major purpose of the study was to locate a significant group of respondents to whom an in-depth survey would be administered. The survey instrument contained a variety of socioeconomic questions, detailed travel questions, and questions relating to travel behavior, modal choice, and, in a limited fashion, opportunity choice.

This paper deals with 2 aspects of this study. The first presents a description of the theory and methodology of the survey. The second gives a socioeconomic and travel profile of those respondents in the survey who lived in households in which no car was owned or in which a car was generally unavailable. As will be seen, car ownership is in itself a poor substitute for car availability. Of the respondents surveyed in carless households, only 21 percent indicated that they never had access to a car. Of the remaining 89 percent of the respondents, 18 percent of that portion, or 14 percent of the entire sample, indicated that they generally did not use a car for traveling to and from any of 14 selected activities. In sum, 65 percent of the basic "carless" population indicated that they traveled by car at least occasionally either as driver or rider to any of a variety of activities.

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SURVEY

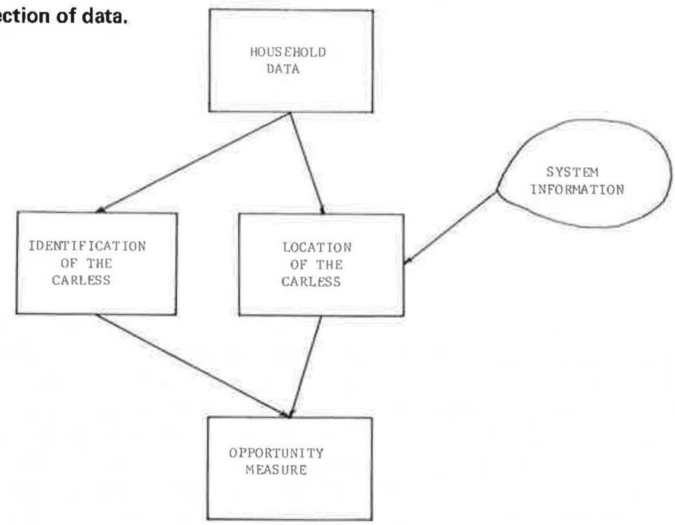
A major task of the study of the carless was the development of a survey to analyze problems that this group incurs when attempting to travel to activities of varying levels of priority. The design of the questionnaire focused on 2 major purposes: (a) identification of the problems of the carless and their categorization by extent and (b) information necessary to propose alternative solutions to these problems. As such, the resulting design was necessarily complex because the subset of applicable problems could not be surmised before the information necessary for postulating corresponding solutions was obtained. The survey was divided into 2 basic sections. The first dealt with the collection of basic household and demographic data, that is, identifications and establishments of respondent groups; the second dealt with the travel and activity behavior and attitudes of the respondent.

A conceptual diagram of the application of the information obtained from the first section is shown in Figure 1. In addition to the usual socioeconomic data, the household data contain extensive information on the household's accessibility to existing forms of transportation and are used to identify carless households and estimate level of mobility (trip frequencies and purposes) for household members. This information, when coupled with system characteristics, such as bus frequency and route information and locations of public facilities, will lead to the development of a measure of opportunity to complete desired activity selection. This process enables the categorization of the study population according to levels of mobility and opportunity, a feature that will be important in the subsequent development of behavioral models of activity and modal selection among the carless.

The second section of the survey was subdivided into 3 components. The first aimed at obtaining information on a group of daily activities as well as desired changes in these patterns; the second was concerned with information on attitudes toward the various activities and priorities among activities; the third focused on information associated with attitudes toward various existing modes of transportation as alternatives for the various activities. The relationships among these 3 components are shown in Figure 2.

Information on the activity pattern of the respondent is obtained in the form of usual frequencies among the various activities, location of the activities, and usual means of transportation to and from the activities. In addition, coupled with each activity is a set of questions on any desired changes in the activity pattern. The potential use of this information is clearly shown in Figure 3 in which simple Venn diagrams are used to demonstrate conceptually the analysis of the data obtained in this section. In com-

Figure 1. Flow for collection of data.



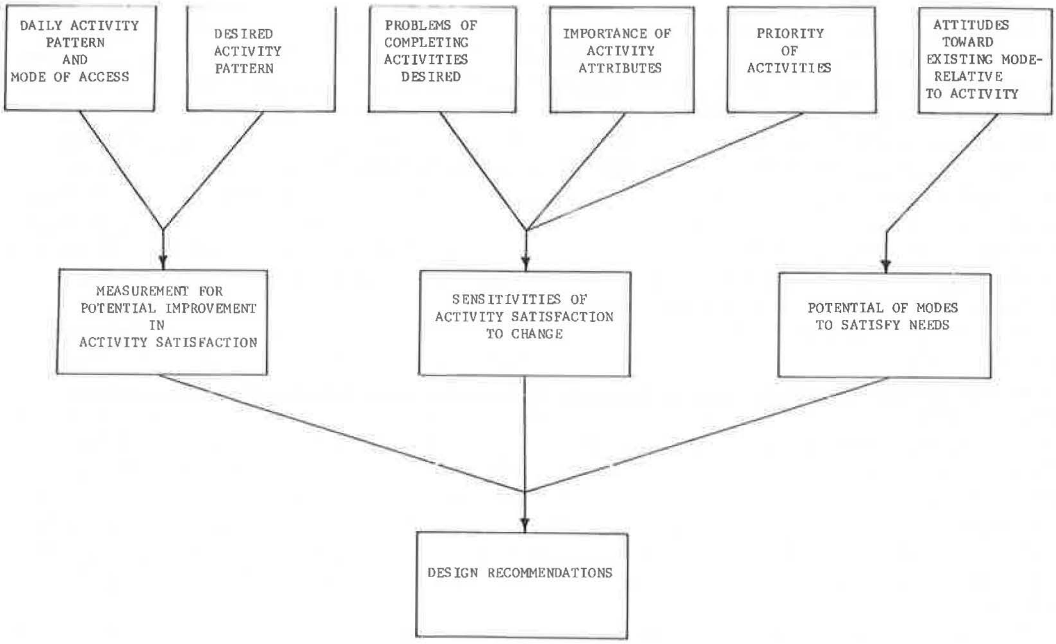


Figure 2. Data collection and analysis.

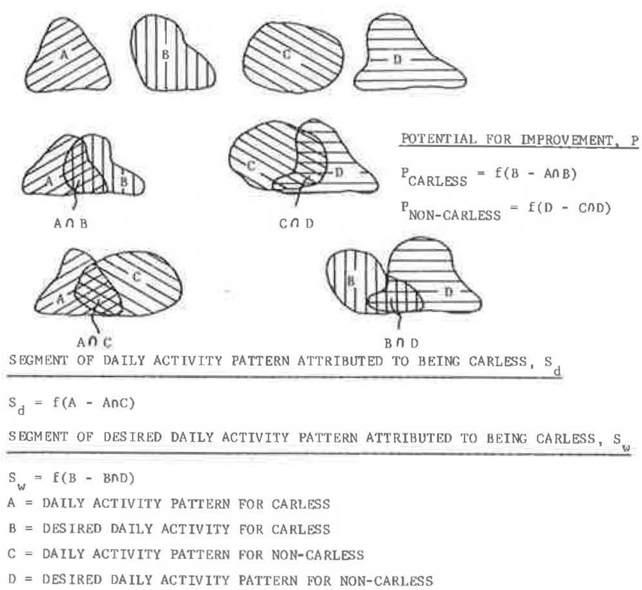


Figure 3. Activity patterns of the carless.

paring the actual daily activity pattern for the carless population with their desired activity pattern, we postulated that the potential for improvement of activity satisfaction among the carless is some function of the portion of the desired activity pattern that lies outside the daily activity pattern. A similar analysis is carried out for the non-carless population. Comparison of the potentials of improvement for the 2 populations can be used to develop a quantitative measure of activity dissatisfaction that is due to being carless. In addition, comparison of daily activity patterns of the 2 groups leads to the postulate that the segment of daily activity pattern attributed to being carless is measured by the activity set of the carless less that which is also contained in the set for a corresponding group in the noncarless population. These can be directly measured by the survey. The frequencies of travel to 14 activities, together with all the aspects of travel to these activities, have been measured for each respondent.

An intriguing comparison also can be made of the desired activity patterns of carless and noncarless groups. One can postulate that the portion of the desired activity set for the carless that is not contained in the corresponding set for the noncarless is a measure of the segment of desired activity patterns attributed to being carless, that is, the degree to which the perceived activity space of the population has been altered solely because of carlessness. A similar argument, of course, can also be made for the noncarless population. An analysis of actual travel patterns of the carless postulated that the differences in travel between these groups is one of quality (5). Being without access to a car gives a different perception of actual available opportunities. These lead to establishing time and cost travel budgets acceptable to each group. This, in turn, permits the establishment of travel priorities. Unmet priorities of the carless caused by transportation (as opposed to available funds) would be a component of the desired activity set.

The second component of this section of the survey was designed to gather detailed information on any problems associated with performing desired activities (separated according to time-, monetary-, and transportation-related constraints), on the importance of being able to perform the various activities, and on attitudes toward the set of attributes that make up the various activities. The experimental procedure used in this section is based on semantic differential tasks. The resulting information can be interval scaled by using the law of categorical judgment (6). Aggregate models for determining a measure of deprivation can be constructed according to the flow diagram shown in Figure 4. In addition, from information collected on the importances of the various activity attributes, models can be developed to predict changes in activity satisfaction that can be brought about by changes in the characteristics of the activities themselves rather than by improvements to the transportation system, which would make the activities more readily accessible.

Finally, information on attitudes toward existing transportation alternatives was collected in the form of semantic differential judgments in the last section of the questionnaire. From this information, determining the potential, through change, of the existing transportation system to satisfy the needs expressed by the respondents will be possible. This information can then be used to infer any increased activity satisfaction that may be brought about by changes in the transportation system.

SAMPLE SELECTION

Sample selection for the survey was based on a biased random sampling procedure in selected areas of Buffalo, New York. Five areas were chosen to get a variety of characteristics to ensure that comparisons could be made between

1. Areas with low car ownership and areas with high car ownership,
2. Areas with reportedly low bus use and areas with reportedly high bus use, and
3. Areas with relatively high median income and areas with relatively low median income.

Detailed characteristics of the 5 areas selected are given in Table 1 (7). Because a companion study deals with travel in the Buffalo model neighborhood area (MNA), this area was not included in the survey. The MNA has the highest no-car ownership and lowest median income in the city.

The survey was administered to 401 respondents of whom 105 belonged to households that owned no cars, 115 belonged to households with 1 car and the car was used for the journey to work, and 65 belonged to households with cars available but had no license (25 in household with the car at work). The survey was designed to determine both household car ownership and the respondent's access to a car either within or outside the household.

Figure 4. (a) Aggregate and (b) disaggregate models.

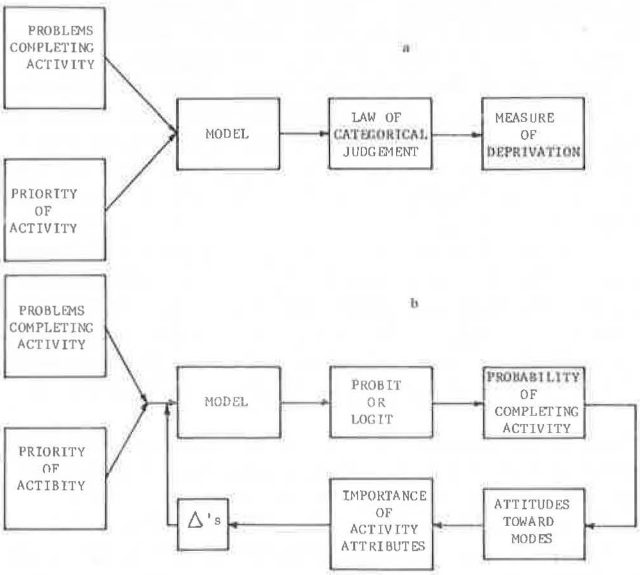


Table 1. Characteristics of study area.

Study Area	Distance to CBD (miles)	Population	Median Income (dollars)	Households With No Car (percent)	Workers Who Journey to Work by Bus (percent)	Workers Who Work in CBD (percent)	Workers Who Work in Rest of City (percent)
1	4.9	20,548	9,297	27	11	8	54
2	4.8	12,698	12,384	15	12	12	57
3	3.3	20,901	8,755	33	24	12	56
4	3.5	22,913	9,458	25	35	14	64
5	1.9	42,029	9,423	40	20	15	59
City		462,768	8,804	34.3	21	12	56

Note: 1 mile = 1.6 km.

Table 2. Characteristics of survey population.

Population	Total Sample (N = 401)		Carless Households (N_0 = 104)		Car-Owning Households (N_1 = 297)	
	Number	Percent	Number	Percent	Number	Percent
Age						
<18	21	5	4	4	17	6
18 to 59	239	61	41	39	198	69
>59	133	34	59	57	74	26
Sex						
Male	154	38	19	18	135	45
Female	247	62	85	82	162	55
Employed	166	41	22	21	144	49
Unemployed	234	69	82	79	152	51

SOCIOECONOMIC CHARACTERISTICS OF THE CARLESS

For the group that owned no cars within the household, respondents indicated the availability of a car from another source for their use. Only 21 percent of this sample never had a car available for their use. Summary totals of the survey population are given in Table 2. The socioeconomic characteristics of the respondents are given in Table 3. Group A refers to those who never have a car available, and group B refers to those who have access to a car with varying frequencies. The table is set up to look at the age groups within each major category, the employment status of the respondents, and whether the respondents have driver's licenses. The major proportion of the respondent population is female (82 percent) and more than 59 years old (57 percent). Of the total respondents in group A, only 4.5 percent have driver's licenses. This compares with 17 percent in group B. Sixty-one percent of the total number of respondents from the survey had driver's licenses. (This actually becomes 78 percent of those in households with cars who have licenses.) A large proportion of those without licenses are female and elderly. Because of their family roles and lack of driver education courses when they were of high-school age, the necessity of getting a license was not great. This, of course, is changing and more young females are getting licenses. Thus, when they become elderly, they will have licenses and will change greatly the current proportions of those with or without licenses. Twenty-three percent of the respondents in group A are employed, but none have licenses to drive. In group B, 19 percent are employed, but, of these, only 25 percent have driver's licenses. The predominant characteristics, then, of the respondents in carless households (regardless of car availability) are that they are female, elderly, and unemployed and have no driver's licenses.

The data given in Table 4 indicate the total sample and carless household response by study area from the field search for the carless. Comparing the data in Table 4 with the census data in Table 1 confirms that those socioeconomic characteristics used to locate the sample served are good predictors of car access (4). For example, area 2, which has the highest car ownership per person and the highest household income, has the lowest percentage of potentially carless individuals. The general prediction that 65 percent of the population is potentially carless (4) (without direct access even if a car is owned by the household) is also borne out from sample characteristics. Table 4 groups the respondents by carless household, households with a car and with the car at work, and households with cars where the respondent had no driver's license. Again, in the carless households, the majority of the sample did have a car available at some time, and the proportion of car-available to car-unavailable respondents was fairly constant throughout all the areas. Because the great number of respondents were unemployed and female, examining nonwork trips in detail and determining their tie to car availability are possible.

Finally, the characteristics of respondents in sample households without cars are markedly different from the sample population in the aggregate or the car-owning population specifically (Table 2). Sixty-one percent of the entire population was in the 18-to-59 age group; only 39 percent of the carless households were in that group, and the remainder were in the over-59 group. The male-female split of the carless was skewed more to the females, and there were 10 percent more unemployed in the carless household group.

TRAVEL BEHAVIOR

In the survey, detailed questions were asked concerning the following group of activities:

Code	Activity
0	Employment
1	Grocery shopping
2	Clothes shopping
3	Convenience shopping
4	Doctor, dentist, or clinic
5	Visiting friends in neighborhood
6	Visiting friends out of neighborhood
7	Bank
8	Church or temple
9	Social activities group
10	School
11	Taking children to school, meetings, lessons, or other activities
12	Bar, ice cream parlor, or coffee shop
13	Paid recreation
14	Park or playground

Questions for each activity included frequency, desired frequency, location, travel time, desired locations, and desired times. A set of questions also was asked regarding frequency of use of mode for 6 specified activities. For example, those surveyed were asked how often they used a car, bus, or taxi or walked for

1. Major grocery shopping,
2. Shopping for odds and ends,
3. Shopping for personal goods, and
4 Visiting friends.

Respondents used a scale from 1 to 7 to answer (1 = always, 7 = never).

The activities and modal frequencies are examined based on categories of car availability as discussed in an earlier section of the paper. Two questions from the instrument were keys to establishing these categories. The first established car use, and the second established availability.

1. Do you have use of a car, from any source, either as a driver or rider?
   a. Yes, as driver and rider
   b. Yes, as driver only
   c. Yes, as rider only
   d. No
   e. Don't know, no answer
2. Is it available to you?
   a. Always
   b. Usually
   c. Seldom
   d. Almost never
   e. Don't know, no answer

In the categorization of the carless, responses a and b to question 2 are grouped together and are considered car generally available; responses c and d are grouped together and are considered car generally unavailable. Figure 5 shows the activities surveyed, the frequencies with which they are performed, and the desire to perform them more or less frequently.

Car availability is also basically independent of the proportion of respondents who participated in the various activities. Shopping of all kinds and visits to bars and coffee shops were done by a larger proportion of the carless than the noncarless. These can be related to personal budget because the noncarless generally had higher incomes than the carless had.

In the question regarding frequency of activity most respondents from the entire

Table 3. Socioeconomic characteristics of carless households.

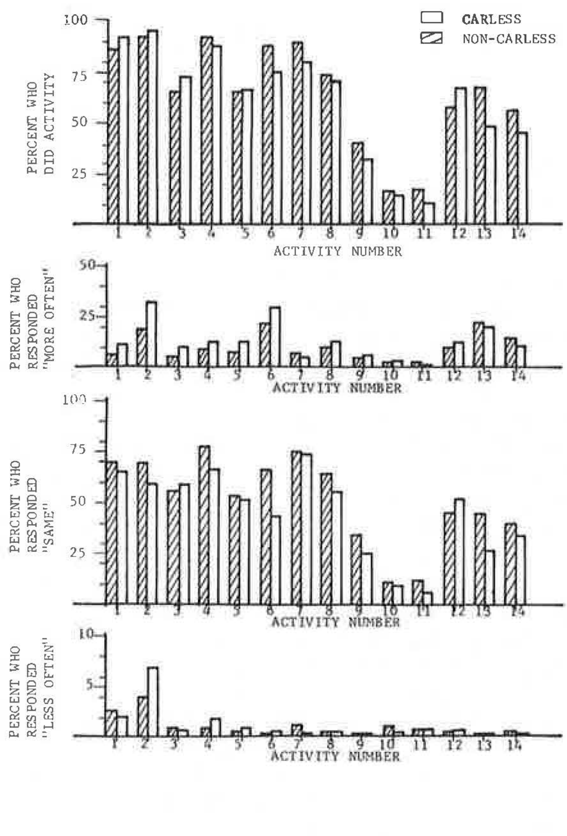
Group	Age	Median Income (dollars)	Employed Males Total	Employed Males Licensed Drivers	Unemployed Males Total	Unemployed Males Licensed Drivers	Employed Females Total	Employed Females Licensed Drivers	Unemployed Females Total	Unemployed Females Licensed Drivers
A	<18	7,800	0	0	1	0	0	0	1	0
	18 to 59	4,985	0	0	1	1	5	0	3	0
	>59	2,988	0	0	4	0	1	0	6	0
B	<18	4,410	1	0	1	1	0	0	0	0
	18 to 59	6,504	3	2	2	1	8	2	19	1
	>59	4,460	1	0	5	2	3	0	39	5

Table 4. Response by sample area.

				Car-Owning Households			
		Carless Households		Car At Work			
Area	Total Respondents	Car Available	Car Unavailable	Total	No Driver's License[a]	No Driver's License	Percentage of Carless
1	77	7	2	25	6	20	63
2	60	3	1	17	3	11	49
3	85	18	4	25	13	21	65
4	67	13	3	29	5	5	67
5	112	42	12	17	2	7	68
	401	83	22	113	29	64	

[a]When the car was used for the work trip, those with no license were tallied and counted again in the next column.

Figure 5. Activity frequencies of respondents.



group were satisfied with their current level of activity frequency. However, more of the carless than the noncarless responded that they would like to travel more frequently than they now do. This set of activities is shown in Figure 5. Shopping of all kinds and visiting friends were noted to be most significant out of the entire activity list.

In a further analysis of the activities, Figure 6 shows actual frequency as a function of car availability. Those who have infrequent or no availability of a car have distinctly different trip frequency patterns than do those who have a car available. Grocery shopping, done slightly more than once a week by those with a car available, is done nearly twice as often by those who do not have a car available. The following analysis of the latter respondent group shows the high frequency of walking to shop:

	Mode				
Direction	Walk	Taxi	Bus	Drive Car	Ride in Car
To store	73	2	4	17	4
From store	70	5	4	17	4

Frequent shopping trips may be made for a variety of reasons that are functions related to both the socioeconomic characteristics of the trip maker and the characteristics of the available system. A large segment of the carless are the elderly and they are members of relatively small households as can be seen in the following tabulation (sample size was small for the over-84 age group):

Age Group	Average Family Size
16 to 54	2.43
55 to 64	2.08
65 to 74	1.72
75 to 84	1.45
> 84	1.6

Shopping for large amounts may be unnecessary for small households, and inadequate or improper storage space may make frequent small trips necessary. Inability to carry packages, frequent availability of store specials, and the pure social aspects of shopping (especially in the neighborhood) would boost this frequency.

Neighborhood visits (activities 5, 12, and 14) also are done with much greater frequency by this group, but paid social activities (activity 14) are done with significantly less frequency. Lack of accessibility to a car obviously limits accessibility to a diverse set of activities, and, from the response, buses do not take up all the slack in travel. Buses are the predominant mode of travel for clothes shopping, visits to the doctor, and visits to friends outside the neighborhood.

Travelers were asked how important improved transportation would be as an incentive to increase the number of trips taken for a series of 6 of the activities. Leisure and recreation and visiting friends were ranked very high, which means that transportation would play an important role in increased trips. Shopping for groceries and necessities also was linked to transportation by this carless group, predominately by the female, 18-to-59 age group. Social visit increases were important primarily to the over-59 age group. Out-of-neighborhood visits became very important to those in the city whose family and friends were in the suburbs.

The same pattern for grocery shopping is indicated in Figure 7, which shows car use. Those with no car use or who could use a car only as a rider shopped for groceries more frequently than those who were able to use a car as a driver. This again occurs

Figure 6. Trip frequencies by car availability.

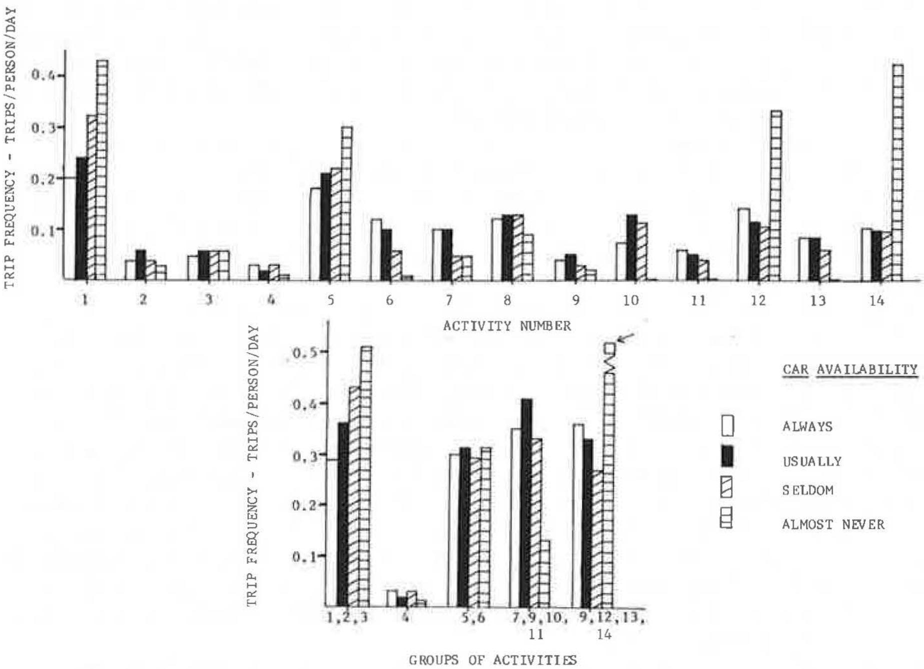
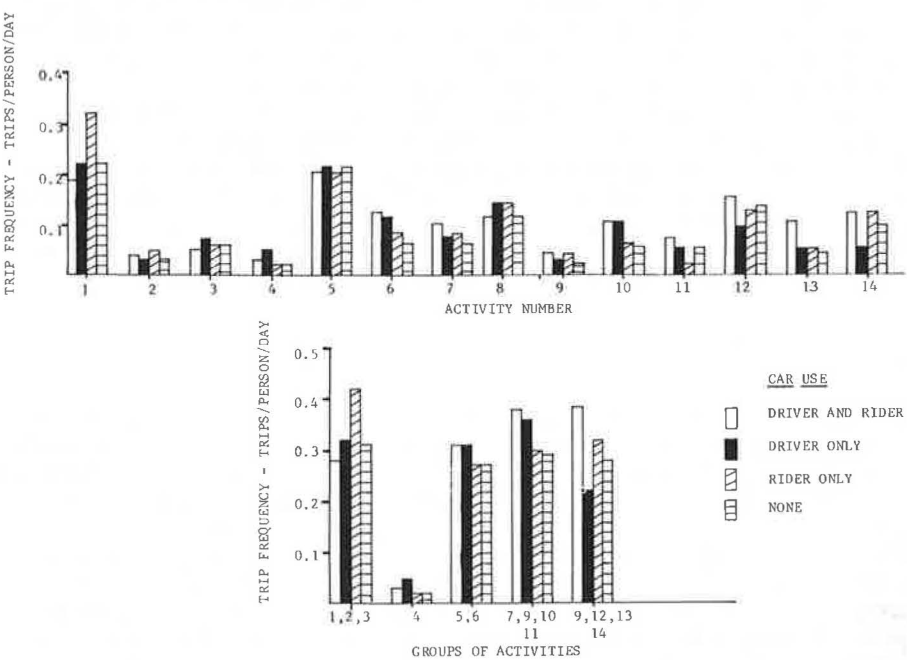


Figure 7. Trip frequencies by car use.



for the reasons previously cited. Activities that can take place within the neighborhood do so at about the same frequency regardless of car use. However, activities specifically cited outside the neighborhood (activities 6 and 12) were done with much less frequency by those who had no car use. Those with no car use can be, perceptually, neighborhood bound. That is, they possess no real sense of the time and distance associated with a variety of opportunities outside their neighborhood.

In a complementary set of questions regarding modal choice, respondents were asked to cite the frequency (on the 7-point scale) with which they used various modes for specific trip purposes. The results of these questions are shown in Figures 8, 9, and 10 for walking, bus, and car. These figures show clearly the effect of car availability on modal choice for the respondents in 2 groups—households that own cars and households that do not own cars.

Walking, as has been noted, is used by most of the carless respondents for grocery shopping; it is used only occasionally by less than 10 percent of the households with cars. Walking for those with cars becomes a more popular mode for other purposes too, especially visiting friends in the neighborhood. The majority of those in carless households find that they can satisfy their other shopping needs (at least sometimes) at places within walking distance. The socioeconomic and travel characteristics of the sample show that most of this group live in the most densely populated area of the city where a large choice of shops exists. The history of Buffalo, like the history of many old urban areas, indicates that the migration of younger people to the suburbs left an older population in the city. Regardless of the reason—tie to neighborhood, accessibility to familiar activities—the elderly are found in large numbers in these areas, and they make up a large proportion of the sample. The results of walking as shown in Figure 8 are consistent with known urban patterns.

The bus is used with little frequency by either group. It is used most frequently by the carless for shopping for odds and ends, visiting friends, and shopping for personal goods. Most of the sample who live in area 5, the largest group of households without cars, are favored also by excellent CBD and crosstown-oriented bus service. This enables buses to be used to shop in the CBD or along the local neighborhood shopping streets, yet bus use is still relatively low. As would be expected, more than 60 percent of those respondents in car-owning households never use a bus for the purposes listed.

The car is used with greater frequency than the bus by the carless for grocery shopping. The importance of this trip seems to create a demand for car availability that is not matched by other activities. The number of carless people who have a car available for the other trip purposes decreases somewhat. The difficulties of grocery shopping without a car become striking when the responses are analyzed. Decentralization of supermarkets, difficulty of carrying packages, and difficulty of using buses in inclement weather make 2 choices necessary for those without cars: (a) get a ride or (b) walk to neighborhood stores, which causes a higher frequency of travel.

CONCLUSIONS

The survey indicated that delineating not only between car-owning and non-car-owning households but also among the various subcategories of those to whom a car was available with varying frequency was possible. Elderly (more than 59 years old) unemployed females are among the most severely affected of those who responded to the survey. However, the conditions of location within densely populated urban areas somewhat alleviate the problems of shopping and social visits. Bus accessibility appears to be marginally important, but, as noted for grocery shopping, occasional car availability was more important to the carless respondents. The fact that, in carless households, more than 75 percent of the respondents indicated occasional or greater car availability shows that traditional modal-split models calibrated by using car ownership as a criterion might well overestimate demand or potential demand for transit.

The carless have been able to satisfy many of their travel needs locally rather than citywide or regionally. Further studies from the survey will investigate the attitudes of the carless groups toward modal attributes and will develop models of travel priority

Figure 8. Walking frequencies for selected activities.

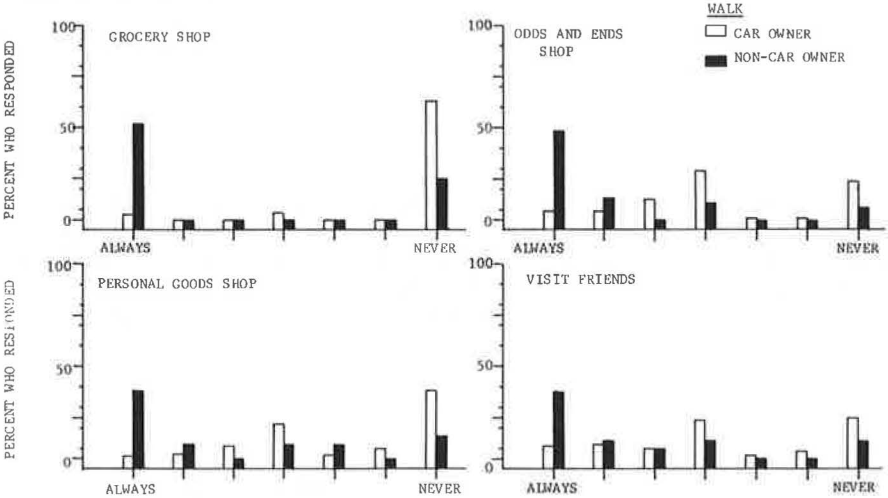


Figure 9. Bus frequencies for selected activities.

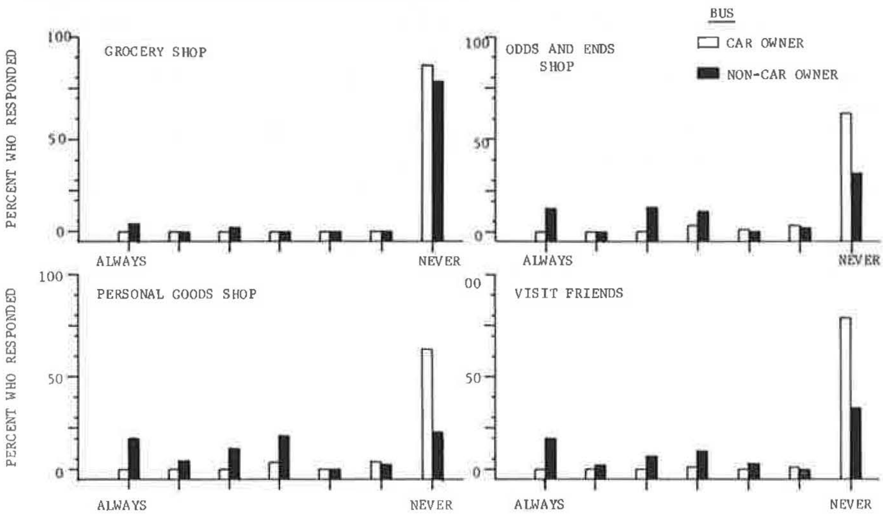
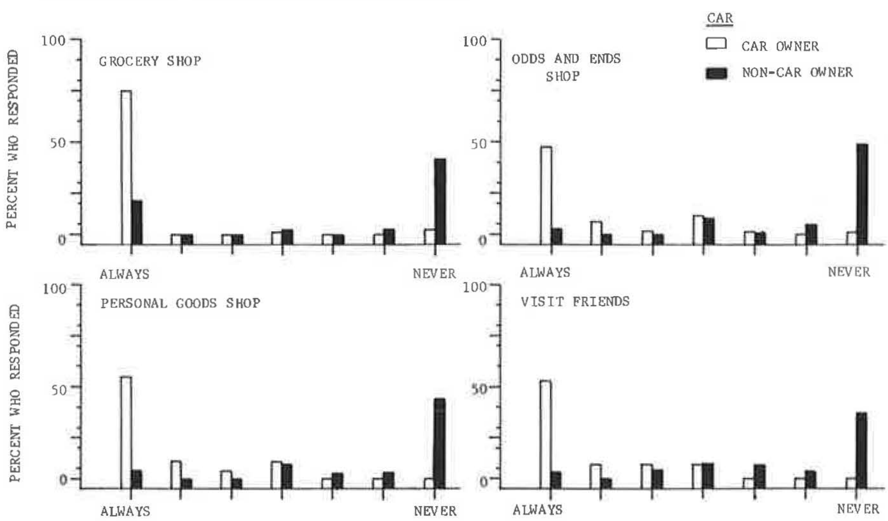


Figure 10. Car frequencies for selected activities.



for these groups.

ACKNOWLEDGMENTS

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LOADING AND SECURING WHEELCHAIRS IN TRANSPORTING STUDENTS

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California has no standard specifications or regulations that specifically address the construction and outfitting of special school buses that transport students confined to wheelchairs. The standard requirements for regular school buses are not suited for buses that carry wheelchairs. Therefore, whenever a new wheelchair bus is proposed, the California Department of Education must issue an exemption from the regular school bus requirements. This practice has led to inconsistency in approved systems. A study was made to assist the department in developing specifications for its wheelchair school buses. In particular, outfitting components, such as loading and securing equipment, were addressed. The study involved visiting 21 organizations including school districts, transportation contractors, and suppliers; documenting systems; and evaluating equipment. This report presents not only findings and specification recommendations but also several questions raised during the study on the behavior of wheelchairs and associated hardware during a vehicular accident. Some of these questions can be answered only by dynamic testing of the equipment.

•SECTION 6807 of the California Education Code states that "the governing board of a school district... shall provide transportation for those pupils whose physical handicaps prevent their walking to school." Section 16852 of the same code gives the California Board of Education the authority to adopt regulations relative to the construction and operation of school buses. The board has issued its specifications for school buses under Title 5, Education, in the California Administrative Code. To transport wheelchair-confined students, a regular school bus or other type of vehicle must be modified by installing specialized equipment. However, Title 5 does not include detailed specifications for such changes, and each school district desiring to transport wheelchair-confined students must first obtain an exemption to the standard school bus specifications outlined in Title 5. This exemption is authorized under section 14321 of Title 5 so that alternative methods of meeting the intent of the California Education Code could be introduced.

Section 2807 of the California Vehicle Code states that "the California Highway Patrol shall inspect every school bus at least once each school year to ascertain whether its construction, design, equipment and color comply with all provisions of law." Because there are no specific standards, laws, or regulations governing wheelchair facilities, the California Highway Patrol has a problem complying with section 2807. Without specific guidelines, highway patrol inspectors are faced with the problem of interpreting the intent of the law that regulates sizes of specific items on regular school buses when they are establishing requirements for similar items on wheelchair buses. For example, they consider the size of bolts required to secure seats when they are evaluating the size of bolts for wheelchair hold-down devices. Because exact specifications are not available, most decisions regarding wheelchair buses are subjective ones. This results in undesirable inconsistency in acceptable systems. A simple solution to the problem is to include within Title 5 specifications for wheelchair school buses. The highway patrol took the first step by drafting some basic specifications, which it submitted to the Department of Education (DOE) with the suggestion that they be expanded. DOE then formed an ad hoc committee and charged it with the responsibility of producing specifications for wheelchair buses.

OBJECTIVE

The objective of this study was to assist the DOE ad hoc committee in preparing specifications for loading and securement facilities used in transporting wheelchair-confined students.

RESEARCH PROCEDURE

Twenty-one different organizations, including school districts, school bus contractors, school bus manufacturers, and a service agency, were visited to determine the types of loading and in-transit securement equipment now being used to transport wheelchair-confined students. The demographic areas that the operators serve vary from city to rural. During each visit, the loading equipment, the hardware components for securing wheelchairs during transit, and the type of passenger securement were closely observed and photographed. In addition, a subjective evaluation was made of the ease of operation of the various components, particularly during adverse conditions such as fire or threat of fire. Also evaluated was the degree to which the components would be a potential hazard to passengers during a vehicular accident. The various physical problems associated with transporting wheelchair-confined students also were discussed with the bus operators.

RESULTS AND COMMENTS

A brief description of the equipment found is included here. A more detailed description, with photographs, is available elsewhere (1).

Vehicles

Two basic types of vehicles are used for transporting wheelchair-confined students by the organizations visited. They are the specially designed school bus (class 1) and the commercial van (class 2). Examples are shown in Figure 1. The van is by far the most popular. The number of class 2 vehicles ranged from 1 to 75/organization; the number of class 1 vehicles ranged from 2 to 25/organization. The average capacity of a class 2 vehicle is 4 wheelchairs; the maximum capacity is 6 wheelchairs. Class 1 vehicles are capable of transporting larger numbers of wheelchairs (up to 21), but the average carried varies from 5 to 10 wheelchairs. Both types of vehicles carry seated passengers in addition to wheelchairs. Wheelchair passengers face forward in all but 3 of the class 2 vehicles. Sideway facing is the exception. Sideway facing with limited forward facing is the norm in the class 1 vehicles. Most of the handicapped transported with the equipment studied are between the ages of 3 and 21 years. A few persons over 21 years also are transported on special occasions. In some vans, the roof was not high enough to allow a high school student of above average height to sit upright in the chair. One organization, however, has a van that has been modified with strengthened walls, raised roof, reinforced door, and raised door clearance (Figure 2). This van has ample head room and is certified by the manufacturer to withstand the static load test of the School Bus Body Manufacturers Association. Most vehicle drivers are women. Male drivers are more prevalent if ramps are used for loading.

Loading

Slightly more than 50 percent of the organizations visited use lifts as wheelchair loading equipment, 30 percent use ramps, and slightly less than 20 percent use elevators (Figure 3). The popularity of lifts stems from a concern, especially on the part of women drivers, about handling either heavy wheelchairs or heavy passengers. Both class 1 and 2 vehicles have been equipped with lifts operated by electrically powered hydraulic pumps or electric motors. Most lifts were mounted in the rear of the vehicle in the interest of vehicular safety because the ramp platform provides added rear-end protection. On the other hand, many operators expressed a dislike for rear-mounted loading equipment because of the increased personal hazard of placing the wheelchair passenger in the street during loading and unloading. One organization mentioned the need to install an interlock to prevent accidental tilting of automatic, folding lifts while loading. Heavy-duty lifts are capable of handling loads much heavier than a wheelchair, which, in itself, is not a disadvantage. However, the excess capacity adds weight to the lift, and this detracts from vehicle performance and increases the effort for manual platform folding. Lifts that block doors can be a problem in an emergency, especially if the vehicle loses power. In some cases, lifts with automatic tilts can be released by manually bleeding the hydraulic lines.

The use of ramps was restricted to vans because of their relatively lower floors. The advantages of ramps include low installation cost, virtually no maintenance, and increased speed in unloading. The main disadvantage is difficulty in loading and unloading. For this reason, most organizations assign male drivers to vehicles equipped with ramps. Even then, 2 people are sometimes needed to load and unload heavy passengers or electric wheelchairs. Driver back injuries have been attributed to the use of ramps. Most ramps are side mounted and can take advantage of curb height to reduce the slope. Side-mounted ramps and lifts that are stored inside the vehicle are sharp, hard objects that could be a hazard in an accident. The padding shown in Figure 4 reduces this hazard. During loading and unloading, this pad is folded onto the roof of the vehicle so that it can protect the passenger's head from the sharp top edge of the door frame.

All the vehicles with elevators were class 1 vehicles. Extensive modification of the vehicle is required to recess the elevator into its side. The driver opens the side doors from the inside of the vehicle and rides the elevator up and down with the wheelchair.

Methods used to prevent the wheelchair from rolling off the platform of the lift or elevator included recesses in the floor and an eccentrically mounted flap on the outboard edge of the platform. The driver's ability to remain with the wheelchair on the lift is an important consideration in minimizing potential problems. Most of the lifts and elevators had this capability, and remote or primary controls were mounted on the lift.

Passenger Securement

A standard automobile seat belt to secure passengers in transit was used by all organizations visited. Twenty-five percent secured passengers to the chair only; 50 percent secured them to the vehicle only; and 25 percent secured them to both the chair and the vehicle. When the belt is either passed around or secured to the wheelchair back support frame and then around the passenger's waist, restraint is dependent on the strength of the wheelchair and its securement. Wheelchairs are designed to be as lightweight as possible, not heavy enough to secure a passenger during a vehicular accident. A belt securing the passenger directly to the vehicle is a more positive system. A direct securement of the passenger to the vehicle serves as secondary securement of the wheelchair. However, this securement should not be counted on too greatly. The chair must be independently secured to prevent its impact from causing injury to the passenger in an accident.

Passengers, particularly young children and those who cannot support themselves when their chairs are subjected to unusual movement, should be secured to their wheel-

Figure 1. (a) Class 1 and (b) class 2 school buses.

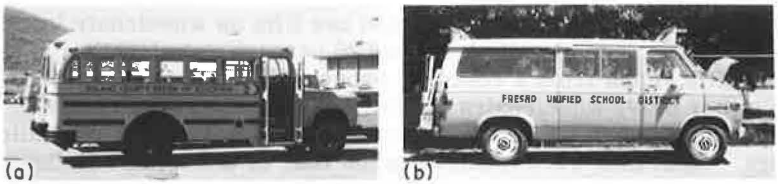
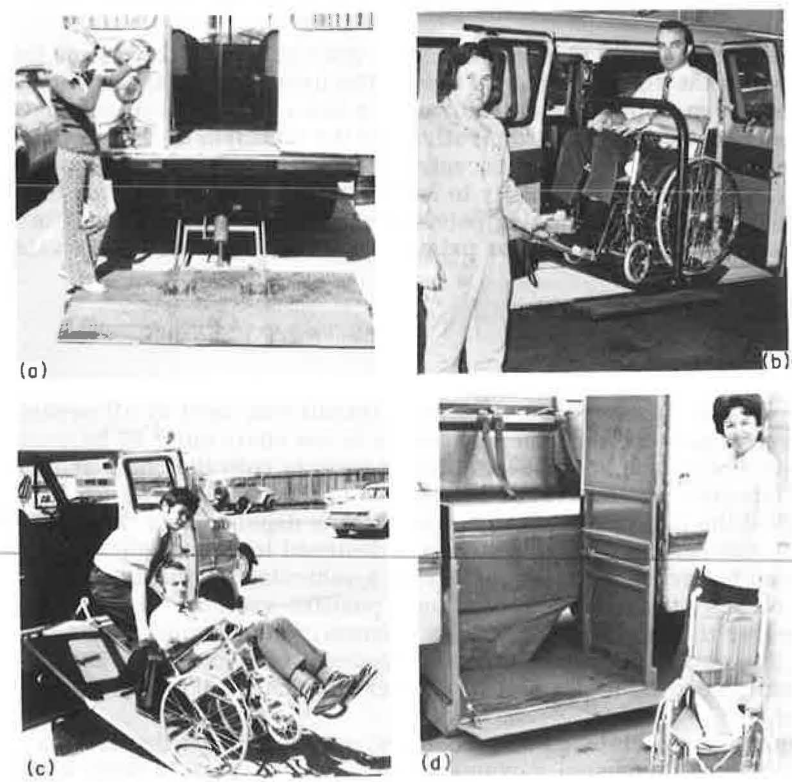


Figure 2. Modified van.

Figure 3. (a) Heavy-duty and (b) swing-in lifts and (c) ramp and (d) elevator loading equipment.



chairs during loading and unloading to prevent them from falling out. Passengers have been known to slide out from under belts restraining both the chair and the occupant. Therefore, some passengers need to be secured directly to their wheelchairs during transit. Belts with quick-release buckles speed securement and release. In some cases, precautions are needed to prevent unsupervised passengers from releasing their belts during transport. In several cases, adjustable tracks or other belt anchorages were fastened to the vehicle by means of sheet metal screws and other fasteners of questionable strength. In one case, the belt webbing was pierced by a sheet metal screw and torn.

Chair Securement

Half of the properties visited secure wheelchairs by attachments to the rims of the large wheels; the others secure them by attachments to the frame. In some cases, chairs positioned sideways could rotate backwards, which could cause the passengers to strike their heads against the vehicle wall. In other cases, docking rails were used to support the backrest frame of the chair and prevent this kind of rotation. Systems that use chains, pins, or locking cams through the wheel rims provide a loose securement and allow some movement of the chair. These devices also cause damage to wheel spokes.

As in passenger securement, wheelchair securement devices were sometimes attached to the vehicle with screws and other fasteners of questionable strength. For example, one device was found anchored by U-bolts made by bending threaded rod stock to shape. Another had a link of its chain welded to an adjustable track fastener in such a way that bending stresses would be induced in the weld metal. Welding and reworking material as were done in these cases may cause undesirable loss of strength unless proper precautions are taken. Because manufactured fasteners of known quality are readily available, such jerry-built modifications seem unnecessary.

The rim clamp shown in Figure 5 provides a fast, simple, and positive securement of the wheel rim. However, 2 clamps alone are not sufficient to prevent rotation of the chair about the rear axle. A third securement point (usually a strap) is used to prevent rotation. Mounting the rim clamp on the side wall reduces its suitability for chairs with varying wheel diameters. Some securement devices were mounted across doorways, thereby obstructing the doors. Devices mounted on floor stands or other permanent fixtures are obstructions that inhibit rapid removal of the wheelchair in case of an emergency.

Many of the frame anchor devices do not connect to the wheelchair frame. They depend on clamping force to secure the chair. An example is shown in Figure 6. If the chair wheels collapse, such devices can lose contact with the frame and no longer provide restraint. The extra loading exerted on them by the clamping force also increases the possibility of wheel failure, particularly if they are overtightened. The chain and S-hook system shown in Figure 7 pulls inward on the caster frame as the threaded rod is tightened. However, weight of the passenger on the chair during normal transit usually is sufficient to overcome this effect. On the other hand, should the bus overturn, such a device would tend to force the chair to close on the passenger.

The possibility of chair rotation about its axis of securement was found in such devices as the T-bar and others with single attachment to the vehicle. Wheel friction on the vehicle floor and passenger securement to the vehicle are the only forces preventing this rotation. In addition, depending on the configuration of the chair frame, some T-bar devices can slide off the sloping chair frame where they are attached (Figure 6). Especially with heavy wheelchairs, the T-bar and hooked-clamp devices do not restrain longitudinal movement. Therefore, a sudden stop or an accident could cause a passenger secured to the vehicle to sustain chair impact from inadequate chair securement.

A 4-belt system (belts attached to the 4 corners of the chair) easily adjusts to chairs of different sizes and positively secures the chair even if the wheels collapse. However,

Figure 4. Inside storage of ramp with padding.

Figure 5. Rim clamps on adjustable track.

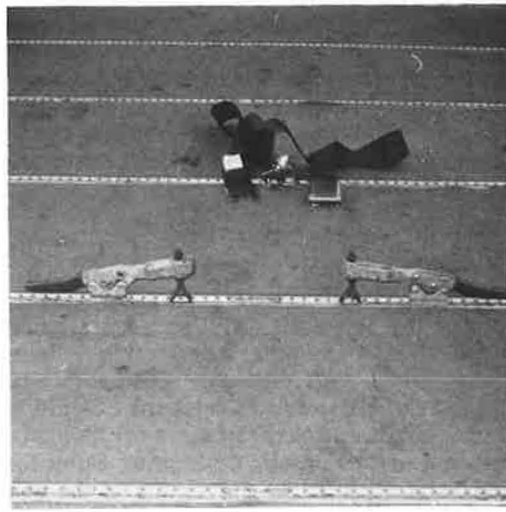


Figure 6. T-bar chair securement.

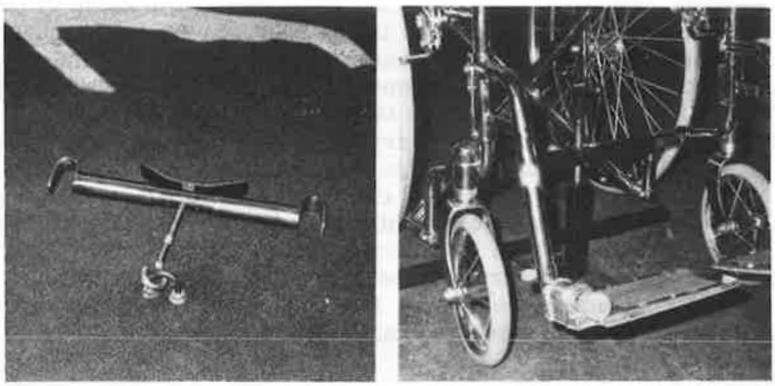


Figure 7. Chain and S-hook chair securement.

this system may require slightly more time than other systems do to secure to the chair or to release during an emergency.

The most versatile wheelchair or passenger securement system uses cargo hold-down equipment. Because this system features a continuous track, numerous locations are available for the snap-on anchors of the system. The greater the number of tracks, the greater the versatility of the system. That the tracks work equally well in the floor and on the wall increases the versatility.

ACCIDENTS AND HAZARDS

The combined efforts of the California Department of Education, the California Highway Patrol, the school districts, the school bus contractors, and the school bus manufacturers have resulted in an enviably low school bus accident record in California (2). They all are to be commended.

For a better appreciation of this record, one should note 2 things.

1. During the 171,246,061 school bus miles (273 993 697.6 school bus km) driven in the 1972-73 school year, there was not a single bus occupant fatality. In fact, there has been only 1 pupil passenger fatality in the last 5 years.
2. There were only 167 pupil passengers injured in 1972-73, which is an injury rate of only 0.95/million miles (0.59/million km) of travel.

This outstanding record reflects a deep concern for safety by those responsible for transporting school students, a concern that was continually manifested during this study. The persons interviewed repeatedly expressed a desire to transport wheelchair students as safely as they transported regular students. But there does appear to be a difference. Regular students are normally transported in a class 1 vehicle, which is equipped with many more safety features than the standard commercial van, which is usually used to transport wheelchair-confined students. The van, a class 2 vehicle, is also the most popular vehicle in use for other special education transportation. This is not to imply that the van is unsafe, but, because it lacks all the safety features added to class 1 buses, it cannot possibly be as safe. Therefore, if all students are to be transported with equal safety, similar specifications are needed for all types of school buses. One of the most striking examples of the need for similarity is gas tank specifications. During the study, everyone expressed great concern for the need to evacuate the wheelchair students rapidly in case of an emergency, yet no extra preventive measures were found to have been made to minimize perhaps the most potentially damaging emergency of all—fire. So catastrophic are the effects of fire that, in such a hazardous situation, rapid evacuation planning is less important then fire prevention because of the problems associated with wheelchair unloading. If fire does occur after an accident, the loading mechanism could jam, the driver could be seriously injured, the bus could overturn, the wheels of a wheelchair could be severely damaged, or a host of other things could occur that would either drastically slow or completely preclude wheelchair evacuation. Fuel spillage is necessary for a serious postaccident fuel-fed fire. Thus the number of fires can be lessened by reducing the number of times fuel is spilled. At least 2 changes can be made in vans that would reduce the likelihood of fuel spillage during an accident; (a) relocating the fuel tank or (b) providing a rupture-proof tank (3). Investigating the problem of postaccident fuel-fed fires on vehicles transporting wheelchair-confined students is beyond the scope of this study. The problem is a serious one, however, and deserves special study.

ADVANTAGES OF SPECIALLY DESIGNED VANS

Modifying a commercial van for transporting wheelchair students instead of using a class 1 bus or a specially built van was discussed during the interviews. Apparently, frequent use of the vans for transporting wheelchair students is motivated by 2 primary factors: low occupancy demand and apparent economy. In most school districts, the density of wheelchair students is low; therefore, the demand for ridership is too small to warrant the use of a large-capacity class 1 bus.

To assume that the commercial, off-the-shelf van costs less than a specially built van is reasonable. But the question is how much less. Most of those interviewed thought that, when the modification of a commercial van, particularly for raising its roof, is included in the total cost, the cost difference between the 2 vehicles would be small. All agreed that, from a safety standpoint and from the standpoint of durability and maintenance requirements, a specially built vehicle would be far superior to an off-the-shelf commercial van. However, until more stringent requirements are placed on the class 2 vehicle, the off-the-shelf van will continue to be the most popular. The advantages of a vehicle designed and built expressly for transporting wheelchair-confined students are so numerous that a cost-benefit study should be made between such a unit and the off-the-shelf van.

BEHAVIOR OF WHEELCHAIRS IN ACCIDENTS

A subject frequently brought up was the possible behavior of the wheelchair during an accident. The most frequently expressed opinion was that the wheels are the weakest part and would probably collapse in an accident. For that reason, many were opposed to using hold-downs that attach to the wheels. However, as far as securement is concerned, a positive attachment to the wheels would prevent excessive movement of the chair even if the wheels did collapse. Therefore, the deciding criterion for acceptance should be any system that precludes excessive movement of the chair during a vehicular accident. Some of the equipment found might be presenting a false sense of security. Although certain types of equipment have been performing adequately during normal use, how they would perform during an accident is highly questionable. For instance, the hardware used to attach some of the equipment to the vehicle appeared to have ample static loading resistance but did not appear to have adequate impact resistance. One can conclude from the difference of opinion on the behavior of the wheelchair and its associated hold-down hardware in an accident that dynamic testing of full-scale equipment is needed.

CONCLUSIONS

Six conclusions can be drawn from the study.

1. Even though the school bus occupancy injury and fatality rate is very low in California, the Department of Education and the highway patrol have a justifiable concern for the need for statewide standard specifications for hardware components on buses used to transport wheelchair-confined students.
2. Use of manufactured securement equipment instead of "homemade" devices should be encouraged.
3. More emphasis needs to be placed on fire-prevention measures for vehicles used to transport physically handicapped students.
4. Static and dynamic testing of wheelchair and passenger securement is needed.
5. The standard commercial van is deficient in the following areas insofar as it is used as a school bus for wheelchair students: (a) headroom for most high-school-age students and (b) safety features comparable to the bus used for transporting other than special-education students.
6. A cost-benefit study, measured with respect to safety, is needed on buses built specifically for transporting wheelchair-confined students.

RECOMMENDATIONS

Three sets of recommendations are offered. The first, the interim set, covers the adoption of hardware component specifications according to engineering judgment. This set should be implemented as soon as possible. The second, the future set, covers action that should be taken to obtain physical test data on hardware components recommended for interim implementation. After these data are collected and evaluated, the specifications should be revised accordingly. The third, the special set, covers 2 areas that concern operators of special-education transportation vehicles even though the subject areas are outside the objectives of this study.

Interim Set

Recommendations on the interim set cover the vehicle floor, loading equipment, and wheelchair and passenger securement.

Vehicle Floor

The floor of the vehicle shall be level and free of projecting mountings or fastening devices for securement equipment when the equipment is not in use, and it shall have a nonskid surface or covering.

Loading Equipment

Six specifications are given for loading equipment.

1. Loading equipment shall have nonskid surfacing in the walkway portion including ramp steps.
2. Lift and elevator equipment shall have stops to minimize the possibility that a wheelchair will roll off the lift platform.
3. Loading equipment shall be provided with protective padding when it is inside the vehicle.
4. Loading equipment that blocks doorways shall be equipped with a manual, externally operated emergency release mechanism capable of clearing the doorway.
5. Controls for lifts and elevators shall be located close to the lifting platform.
6. Ramps carried in a vertical position inside the vehicle shall be secured at their top during transit.

Wheelchair Securement

Eight specifications are given for equipment for securing wheelchairs during transit.

1. Equipment shall consist of woven webbing or metal fasteners. The webbing shall be of approved cargo or seatbelt type. Fastenings of webbing to mounting points shall be in accordance with manufacturer's specifications. All fasteners shall have a rated capacity of not less than 3,000 lbf (13 350 N).
2. A minimum of 2 fasteners for each wheelchair shall be required. Each shall be mounted separately in the vehicle and have separate points of attachment to either the frame or wheels of the wheelchair.
3. Fasteners shall be mounted so that the chair cannot move more than 3 in. (7.6 cm) in either a straight or circular direction and cannot tip if the vehicle overturns.
4. Fasteners shall be secured to the vehicle with not less than $^3/_8$-in. (0.95-cm) bolts, lock washers, and nuts or self-locking nuts of a strength designation not less

than Society of Automobile Engineers grade 5. The mounting bolts should pierce the vehicle frame, subframe, body post, or equivalent metal structure. If they fail to pierce any of those areas, a reinforcement plate or washer not less than $\frac{1}{16}$ in. (0.16 cm) thick and 2 in. (5.1 cm) square or 2.5 in. (6.35 cm) in diameter shall be provided between the bolt head and the metal pierced.

5. Fasteners shall be capable of restraining the wheelchair if its wheels collapse.
6. If adjustable tracks are used as part of the securement equipment, the tracks shall be secured to the vehicle at intervals not less than those specified by the manufacturer.
7. Where webbing equipment is used, release buckles shall be positioned to have direct in-line tension.
8. Electric wheelchair batteries shall be secured to the wheelchair during transit.

Passenger Securement

Each passenger shall be secured to the vehicle by a standard webbing seatbelt secured to the vehicle in the same manner as the chair securement equipment except that attachment of the seatbelt to the vehicle may be made by one $\frac{9}{16}$-in. (1.4-cm) or two $\frac{7}{16}$-in. (1.1-cm) bolts. Passengers who cannot prevent themselves from falling from their wheelchairs shall be secured to their wheelchairs by a standard webbing seatbelt.

Future Set

Static tests on that equipment that, by engineering judgment, appears to have less than desired strength shall be performed. Crash tests of prototype vehicles containing simulated wheelchair students shall be performed. The students shall be instrumented to obtain body reactions during the test. Interior movies should be taken to record counterreactions of students and equipment; special attention should be paid to the behavior of the wheelchair and its securement equipment.

Special Set

A probability and preventive study on fuel-spillage postaccident fires involving commercial van vehicles shall be conducted. A cost-benefit study, measured with respect to safety, on a low-volume vehicle designed and built specifically for transporting wheelchair-confined students also shall be conducted.

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TRANSPORTATION MOBILITY ANALYSIS OF THE HANDICAPPED

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Handicapped people are one of the neglected minorities of transportation planning. For decades, their needs in transportation have been neglected in favor of the needs of the overwhelming majority. This has meant that, in a society in which mobility is a prerequisite of living, the handicapped are forced to travel very little and either depend on their friends and family for transportation or pay the high cost of special transportation. Handicapped people make up about 11 percent of the population. They are, though, divided by numerous disabilities each of which has its own special limitations. This paper studies the mobility of the handicapped in terms of broad functional classification. In terms of individual personal mobility, a 6-step classification from needing a person's help in moving to no limitations is analyzed. The analysis also includes means of travel, number of trips made, cost of travel, opinions on the adequacy of current conditions, and possible improvements. Handicapped people, especially those with severe handicaps, made fewer trips, depended more on family and friends to drive them, used more expensive travel modes, and were willing to pay more for any new transportation than the average citizen. Furthermore, it was found that improvement in transportation will have to be of at least 3 types: improvements for the ambulatory, improvements for those in wheelchairs who can travel 2 or more blocks (negotiate curbs), and improvements for those in wheelchairs who cannot travel 2 or more blocks. Improvements would range from relatively minor bus modifications, such as lower stairs, to new, special door-to-door services.

•ALTHOUGH many studies have been done on the physical problems that handicapped people have with using public transportation systems, little has been done to determine their travel characteristics and their transportation needs. This study does this in the moderately large (1.2 million people) Denver metropolitan region. An estimated 250,000 people with various handicaps live and work in Denver. The study discussed in this paper covered 4 areas.

1. The chronically handicapped were identified. The handicapped are not a single, well-defined group but are many types of people with many different types of disabilities and combinations of disabilities. Furthermore, handicapped people are represented by a large number of agencies and social organizations that are extremely specialized and, from the transportation point of view, often overlapping.
2. Current travel habits of handicapped people were determined. Most handicapped people are assumed to travel to some extent. Data are needed on how many trips are made for work, school, shopping, and other purposes and what means are used for these trips.
3. The determinants of current transportation usage (that is, mode-determining factors, number of trips, and cost to users) were examined. From this, developing exploratory hypotheses that can be used in planning services may be possible.
4. Opinions of the handicapped (what is thought of the current situation, what improvements are thought to be most helpful, and how an improvement would change

life-styles) were investigated.

SURVEY DESIGN

The survey was designed to bypass one main problem—the lack of centralized information on who handicapped people are, where they live, and how to contact them. The resulting design was to go through agencies and organizations that serve or represent the handicapped. Most of these organizations were contacted through the Denver Regional Transportation District Advisory Committee on the Handicapped. Ten volunteered to distribute the questionnaire to about 250 individuals. Of these, 119 were returned. Each of the agencies was asked to distribute questionnaires to a selected proportion (between 10 and 20 percent) of their clients. They were asked to select a sample that was representative of their clients. This means that the sample was not random and cannot be construed to represent the entire population of handicapped people. In fact, a large but unknown number do not have any contact with these organizations. Also, because the sample from each organization was small, the survey was not biased by a single organization. Therefore, the sample can be considered a reasonable approximation of the people who are represented by the type of organizations that cooperated. These organizations represent mostly people who have disabilities of the limbs or neuromuscular disorders rather than handicaps such as blindness or deafness. This survey, to a large extent, was limited to people older than 15 years.

QUESTIONNAIRE DESIGN

The questionnaire was designed to obtain information in 4 areas: demographics, disabilities, travel habits, and opinions. The demographic questions were included to help identify the person, provide some general information for analysis of determinants, and, most important, serve as a check for comparison with the general population to see whether serious discrepancies occurred. Demographic variables include many of the common indicators: race, sex, age, income, employment, and driver's license.

Two questions were asked and evaluated about the person's disability. The first question was a checklist of descriptive terms common to various handicaps. The respondents were asked to check as many as applied. This question was used to get an idea of the distribution of the disabilities in the sample and to serve as a further demographic check. The second question was designed to get an understanding of the personal mobility of the person and was based on the following classification of handicapped people (1):

1. Must stay in bed all or most of the time;
2. Must stay in the house all or most of the time;
3. Need the help of another person to get around inside and outside the house;
4. Need a special aid, such as a wheelchair, cane, or crutches, to get around inside and outside the house;
5. Do not need any aid or help of any person but have trouble getting around freely; and
6. Not limited in any of the ways mentioned.

As a result of early observations and test questionnaires, item 4 was observed to be more useful if split into the following 3 categories:

1. Need a wheelchair to get around but cannot move out of it;
2. Need a wheelchair to get around but can move out of it; and
3. Need a special aid, such as a cane or walker, to get around inside or outside the house.

Great differences in mobility were observed among these 3 categories. Those who cannot get out of wheelchairs generally have heavy electric wheelchairs that require use of a van with a lift or ramp. Those who can move out of wheelchairs can slide into the seat of a car. This makes taxicab service available to them. Those who can walk may be able to use the bus service and definitely can use automobile and taxi service. A summary of the mobility classes is given in Table 1. After completion of the survey, we found that no one from classes 1 or 2 had responded. Therefore, this variable, mobility, has a range of 3 to 8.

The section on travel habits asked 2 questions. The first requested information about the means used to make trips to work or school, stores, doctors, and elsewhere. The second asked for the number of round trips to these places.

In the section on opinions, 8 questions were asked about the availability of public transportation, how much people were willing to pay, and whether they felt that transportation was a factor in selecting a job or home. Two questions were asked on how transportation might be improved to serve them better, and a final question was asked on how improved transportation might change their life-styles. The purpose of these questions was exploratory, to get new ideas on what might be acceptable. To handicapped people most of these questions were open ended and supplemented with a checklist of common responses to stimulate thinking.

CURRENT TRAVEL CHARACTERISTICS

This section relates the current travel characteristics of handicapped people to their disabilities as indicated by mobility. The characteristics covered are means of travel and number of trips. These are broken into work trips and nonwork trips.

A summary of the means of getting to and from work is given in Table 2. Several things can be seen from these data. First, a large portion of those responding do not have jobs. Second, handicapped people depend a great deal more on public transportation than the general population does. Third, those in the lower mobility classes (classes 3 and 4) depend almost exclusively on ambucab or other people for travel.

Table 1. Mobility classes.

Class	Description
1	Must stay in bed all or most of the time
2	Must stay in the house all or most of the time
3	Need the help of another person to get around inside and outside the house
4	Need a wheelchair to get around but cannot move out of it
5	Need a wheelchair to get around but can move out of it
6	Need a special aid, such as a cane or a walker, to get around inside or outside the house
7	Do not need the help of another person or a special aid but have trouble getting around freely
8	Not limited in any of the ways mentioned

Table 2. Means of getting to and from work.

	Percentage of People							
Mobility	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	All That Work	General Working Population
Drive myself	0	0	30.3	18.2	14.3	0	21	74
Take bus	0	0	0	0	28.6	46.2	14.8	4
Take taxicab	0	0	0	0	0	0	0	2
Use ambucab	22.2	26.9	21.2	4.5	0	0	21.0	—
Walk	0	0	0	0	0	46.2	7.4	6
Others drive me	22.2	15.4	9.1	27.3	0	0	18.5	10
Other means	11.1	19.2	15.2	4.5	7.1	0	16.0	5
Do not work	44.4	34.6	24.2	45.5	50.0	7.7	—	—

Ambucab is a taxi service that uses a van with a ramp for loading and unloading wheelchairs. It is expensive; average fares range from $6.00 to $12.00. The automobile is used mostly by paraplegics (class 5) and the ambulatory (classes 6, 7, and 8). The bus, which is inaccessible by wheelchair, is used exclusively by those who are ambulatory.

The number of work trips is related closely to having a job or going to school. Forty-five percent reported that they made no trips to work or school; 41 percent made 5 trips; and 11.2 percent made from 1 to 4 trips per week, mostly to school. In the area of nonwork trips, the significance of transportation services is more important. The nonwork trips considered were trips to the store, trips to the doctor, and trips to other places for various reasons. Because a person is most likely to use the same means for all nonwork trips, these have been consolidated in the following sample percentages.

Means	Percentage	Means	Percentage
Drive	20	Walk	7
Bus	5	Others drive	49
Taxi	4	Other	2
Ambucab	8		

The percentage of those using ambucab is high because many handicapped people use this service to go to the doctor and are reimbursed by vocational-rehabilitation or welfare programs. The most important thing that this tabulation shows is that half of the respondents depended on others to drive them. This generally holds through all of the mobility classes. The generalization that was extended for work trips seems to hold here. That is, those that are less handicapped seem to use less expensive modes except that all classes seem to depend on others to drive them. Handicapped people make relatively fewer trips than the general population does (3.4 trips per week versus 4.6 trips per week) (2). A large portion of handicapped people make less than 1 trip per week (about 45 percent of those in class 3 are in this group).

OPINIONS

Three of the questions in the section on opinions gave meaningful results. The first, which concerned the price that a person is willing to pay for transportation, is an important indicator of dependence. Again the previously mentioned pattern shows. Those who are more severly handicapped feel that transportation is more important and are willing to spend more for it. On the average, handicapped people are willing to pay $1.22 for a trip to the doctor. Handicapped people in class 3 are willing to pay $2.80 for a trip to the doctor.

Answers to the second question indicated that transportation is not an important factor in selecting a home or a job. Other more important reasons may be such things as concerns of parents or other family members and job availability.

The last question dealt with how bus service might be improved to serve handicapped people better. The answers drew a pattern. For those in wheelchairs, lifts and tie downs that make the bus accessible and safe are important. For those who are ambulatory, physical improvements such as lower stairs, wider doors, and larger route signs, driver courtesy, and changes in management policies (eliminating long waits for transfers between routes) are important.

CONCLUSIONS

As a result of this study, handicapped people can be said to be a large but neglected minority. This is probably because handicapped people are a diverse population. Their income level varies, although usually they are poorer than the average American. Their demographic characteristics also vary. They live in every sector of the city and want to go to all other parts of the city. Handicapped people can be said to have the same desires and needs for travel as everybody else.

Handicapped people now use all modes to a varying degree. The mode that is most often used by handicapped individuals depends greatly on the specialized needs of the individual. Some generalizations can be made, however. All handicapped people are more dependent on their families and friends to drive them on trips than most people in the general population are. Those who are more seriously disabled are dependent on only 2 modes of transportation: friends or family who have a van with ramp or lift and ambucab. Only a few can drive. The remainder, the ambulatory, have the most modes available to them. They can get into and out of cars easily, they can use taxicabs, and many can drive. They also can use buses and other forms of public transportation.

Handicapped people, on the average, make fewer trips than the general population does. There was found to be no great difference in the number of trips made by each handicapped person, but there were large numbers in each class who did not make even 1 trip per week.

About half of each group worked, which means that about half made 5 round trips per week for that purpose. The remainder averaged a mere 3.5 round trips per week.

The price that handicapped people pay for transportation is high if not in dollars then in wear and tear on families and friends. The average price they are willing to pay is $1.22; those in the more disabled categories usually are willing to pay more. This is due to the high cost of trasnportation; fares range up to $12.00 for ambucab and $5.00 for taxicabs.

Transportation improvements for the handicapped will have to be for at least 3 types—those who can walk, those who can get around easily in wheelchairs, and those who cannot get around easily in wheelchairs. The easiest improvements, which have the added advantage of being useful to the general public, are those for the ambulatory. The best thing for them is an expanded bus system (or other means of public transportation) with some relatively minor modifications. Most useful for them would be lower stairs and wider doors for entrance and exit. Also of use would be reserved seats near the front so that they can be seated before the driver gets moving. Improvements for those who can get around easily with a wheelchair would include modifying buses with wheelchair lifts and means of tying down the wheelchair. This could be done with buses on regular or modified routes. The handicapped, in this case, would have to be able to go 2 or more blocks to a stop. Improvements for the person who is not able to negotiate in a wheelchair in two or more blocks will have to be door-to-door transportation in a vehicle with lifts and tie downs. Some of these people also will need attendants.

If these improvements are made, handicapped people will use them. They do not travel as much as most people. Indications are that they would if the cost was lower and the transportation was more accessible.

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